**Peace and Security Review**
Vol. 8, No. 17, Second Quarter, 2018, p.44-94

# Water Security in India
# Threat Mapping: Impact of Climate Change

*Sourina Bej*[1]

## Abstract

Water has been a much discussed topic in India in recent years. Starting from the government's decision on inter-river linking, construction of dams to localised state conflicts over sharing, water touches a chord across religion both ethnically and politically. Hence if water becomes skewed owing to continuous lack of rainfall and simultaneous exploitation for human consumption, it could soon attain a national narrative that would have a bearing on the national economy, agricultural output, religious tourism (given that river is the religious lifeline of the country) subaltern conflicts and much more. The report illustrates five contributing factors/parameters/ issues to water insecurity such as: ground water depletion, glacial retreat, rainfall, temperature fluctuation, national water governance and civil society initiatives such as various water conservation practices. The issues were then studied in each ecological zone to understand the broader link between the causes of water scarcity and climatic variability. Following this, a table is compiled to measure each parameter as a step to under the vulnerability. It is based on this the following projections are being made in two subdivisions: Regions and Issues. In India, the 'scarcity' dilemma with regard to water security lies in inefficient water distribution/management and climate change is a mere catalyst to the existing peril. The data analysed gives us a picture that the climatic changes affecting South Asia is in line congruent with the global climate change conditions.

Keywords: Water, Security, India, Human security, Environment.

## Water Security in India: Threat Scenarios

With the third consecutive year of severe summer, season of drought in Central India, late monsoons, flood in northern *Shiwalik* belt andless winter months,

*1 Sourina Bej is Research Associate in the ISSSP at National Institute of Advanced Studies, Bangalore, India. She can be reached at: sourinabej92@gmail.com.

climatic changes in India are much graver a problem than acted upon. Further severe are its impact on food and water availability. Water has been a much discussed topic in India. Starting from the government's decision on inter-river linking, construction of dams to localised state conflicts over sharing, water touches a chord across religion, ethnicity and polity. Hence if water becomes skewed owing to continuous rain failures and simultaneous exploitation for human consumption, it could soon attain a national narrative that would have a bearing on the national economy, agricultural output, religious tourism (given that river is the religious lifeline of the country) subaltern conflicts and much more.

This report is an attempt to give a nation-wide projection on possible scenarios of water insecurity in India based on qualitative understanding of water utilisation and management in the country. In this aspect, the report looks at the impact of climate change on water availability by answering the basic question: How much role does Climate Change play in causing water security? Or is it merely aggravating an existing peril which is human induced?

The report has divided India into 20 agro-ecological zones[2]. Five contributing factors/parameters/issues to water insecurity have been identified: ground water depletion, glacial retreat, rainfall, temperature, national water governance and civil society initiatives such as various water conservation practices. The issues were then studied in each ecological zone to understand the broad link between the causes of water scarcity and climatic variability. Following this, a table is compiled to measure each parameter as a step to under the vulnerability. It is based on this the following projections are being made in two subdivisions: Regions and Issues.

## Region-wise threat projections:

- The Deccan plateau region of Maharashtra Andhra Pradesh, Telangana and Eastern Coastal Plains of Northern Tamil Nadu is a critical water scarce zone. With departure from normal rain, 34 districts of Maharashtra, especially Marathwada and Vidarbha region is facing drought with has also seen high rates of farmer suicides.
- The Western Plain and Kutch peninsula which has an arid climate has prolonged and continuous water scarcity problems. States of Haryana

2 *The agro-ecological zones are by the National Bureau of Soil Survey & Land Use Planning. It is based on the growing period that takes into account effective rainfall, soil groups and delineated boundaries adjusted to district boundaries with a minimal number of regions.*

and Punjab, considered the rice bowl of India, is heavily dependent on groundwater for its consumption. In addition less rain and dry winters have affected the water table with little chance of water level recharge. Hence better water management could be done by using the open source river water with canal or and tank based irrigation. Poor water quality is also a major environmental issue in India as most of its river networks, lakes and surface water are polluted. As a result, more than 100 million Indians live in areas where water is severely polluted. In the same zone, states like Rajasthan and Gujarat has combated the issue of water scarcity with rain water harvesting methods.

- Another zone of water scarcity is the Northern Plains of the state of Bihar. The region is prone to extreme climate of drought, downpour (flash floods) and long winters. This calls for an effective disaster management and early warning system in place which the region lacks hence water utilisation and management becomes critical at the times of disaster.
- With warming of the Deccan plateau, the Central Highlands is the next zone who could bear the impact of water scarcity. Central Highlands is the zone adjacent to the Deccan Plateau. With water slowly become an issue in the central Deccan States, the highlands will feel the pinch of less rain. Hence if caution and efficient water management is not done, it could soon become problematic.
- The region of Western Himalayas and Northeast can be seen as a region with low water scarcity problems. Largely credited to a lifestyle revolving around environment and ingrained water conservation practiced by the people.
- The eastern Coastal Plains similar to the Northern plains is also disaster prone. Frequent cyclones, sea level rise, tidal erosion and simultaneous over use of groundwater has led to salinity intrusion which has extended up to 30 to 40km inland. The salinity rates of wells have increased after tsunami on 26th December 2004. Hence water scarcity in this region is different from the rest of the country. The per capita availability of water in the zone has not reduced rather it is the per capita availability of usable water that has reduced significantly.

## Issue-wise projections:

- **Groundwater:** With over half of Indian population dependent on groundwater for water consumption, recharging of water level is the most critical for water security. The zone of Deccan Plateau is critical will very low underground water level going beyond 40bgml. In Maharashtra, over drilling of borewells to the depth more than 1000ft has led to groundwater shortage. In addition, severe heat wave incident has turned the cotton belt into a drought prone region. Similarly, a critical underground water scarcity can be observed in Tamil Nadu. This eastern coastal region state has come to face the water problem due to unchecked urbanisation and encroachments on

wetland areas, lack of timely de-silting of water reservoirs and no flood zone planning. In the western plain of Haryana and Punjab, dependency on groundwater is optimum and there has been a 8ms water level fall in the last 5 years. Punjab extracts 145 per cent water from ground against an average 100 per cent recharge and Haryana extracts 109 per cent. In Central highlands, 48% of the wells show a decline in water level. In the Northern Plains, the decadal mean of groundwater fluctuation doesn't indicate abrupt drop. But being a disaster prone zone, groundwater utilisation becomes problematic. In winter months the western Himalayan states of Jammu and Kashmir faces acute to less rainfall. In addition to that, 50 water bodies in Jammu have been encroached upon to build tourist hotels. This will go on to affect the groundwater level. The problem isn't acute not but it might be visible with gradual temperature rise and change in weather patterns. In the Kutch peninsula, ground water level has remained close to 2 to 40bgml. Fresh water availability is less because it is in the shallow levels and saline tracts.

- **Rainfall:** There has been a uniform shift in the rainfall pattern with late monsoon onset, erratic rain and extreme downpour (resulting in floods) being the norm. The Deccan plateau has experienced a departure of normal monsoon rainfall trend, as per the IMD and few regions in the region have received deficient rainfall with negative departure of -42%. On the other hand the northern plains have seen rainfall on an increasing trend. The number of rainy days has increased but so has the intensity of rain. This has run the risk of mountain floods. Given that they are tourist spots, it will run the risk of being more disaster prone. In Rajasthan and Gujarat, there is an increase in decadal rain but simultaneous increase in temperature. This rainfall anomaly has different impact in different region. Because both the open and underground water sources are rain fed, this erratic pattern has affected the freshwater availability.

- **Temperature:** Like erratic rain, even the increase in temperature is a uniform phenomenon in the country. The Western Himalayan states have witnessed a rise above normal by 1C.In Central Highlands and Deccan region, the number of hot days and with it the heat waves have increased. In the north eastern region, temperature rise has been felt in terms of warmer winter months. Temperature may not have a direct bearing on water security but it's impact on the rain pattern has left a bearing on the water resources.

- **Glacial Retreat:** A 21% de-glaciations has been recorded in Jammu and Kashmir. Similarly, the Northern Plains is a frequent victim of floods due to river water overflowing. The Gangotri glacial (source of Ganga) have retreated by over 3 kilometres since 1817. Though a three-kilometre retreat over two centuries might seem negligible but the rate of retreat has increased sharply since 1971. Due to temperature rise, small lakes have formed on top of the glacier which in turn has led to the flooding of lower riparian plains.

- **National Governance and civil society initiatives:** It has been observed that most of the state sponsored schemes meant for water conservation have not incurred lasting positive results. From water conference, *Paani Bachao Abhiyan*, *Atal Talab Yojna*, to 100 ponds restoration scheme in the Deccan region lacked the intended reach and is marred in corruption. It is only the north eastern region and the Kutch peninsula that the use of check dams, mud dams has successfully helped in reviving the river. Secondly, dependency on the Narmada canal than groundwater has incurred positive result to combat water scarcity in the zone.

## Threat Map: Assessing impact of Climate Change on Water Security

| Zones | States | Ground-water Depletion[3] | Rainfall[4] | Temp[5] | Glacial Retreat[6] | National and civil society initiatives[7] | Impact of Climate Change[8] |
|---|---|---|---|---|---|---|---|
| Western Himalayas | J&K, Himachal Pradesh | High | Normal to deficit | Increase | High | Isolated | Medium |
| Western Plains and Kutch | Gujarat, Rajasthan, Haryana, Punjab | Medium to High | Deficit | Increase | | Effective | Medium to High |
| Deccan Plateau | Andhra Pradesh, Karnataka | High | High Deficit | High Increase | | Isolated | High |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Deccan Plateau** | **Maharashtra** | **High** | **High deficit** | **High Increase** | - | **Ineffective** | **High** |
| **Northern Plains** | **Bihar** | **Medium** | **Heavy** | **High** | **Visible** | **(No Data)** | **High** |
| **Central Highlands** | **Madhya Pradesh, Uttar Pradesh** | **Medium** | **Deficit** | **Increase** | | **Ineffective** | **High** |
| **Eastern Ghats** | **Tamil Nadu, Kerala** | **High** | **Deficit** | **Increase** | | **Nil** | **High** |
| **Eastern Coastal Plains** | **Odisha** | **Medium** | **Deficit** | **Increase** | | **Effective** | **Medium** |
| **Western Coastal Plains** | **Goa** | **High** | **Deficit** | **Increase** | | **Nil** | **Medium** |
| **Bengal and Assam Plains** | **West Bengal, Assam** | **Medium** | **Heavy** | **Increase** | | **Isolated** | **High** |
| **North Eastern Hills** | **Arunachal Pradesh, Sikkim, Meghalaya, Manipur, Tripura, Nagaland, Mizoram** | **Depletion** | **Heavy** | **Increase** | | **Isolated** | **Low to Medium** |
| **Islands** | **Andaman and Nicobar Islands** | **Medium** | **Normal** | **Increase** | | | **(No trends due to lack of data)** |

3 *The high limit indicates water level below 40mbgl, medium indicates water level within 30 to 10mbgl and low indicates water level within 5 to 2mbgl. Data from 2016 Water Level Map by Central Groundwater Board.*

4 *The high deficit limit indicates rainfall within -3.0 mm/yr, deficit indicates rain below 0 to -3.00 mm/yr and normal to heavy is rainfall above 3.6mm/yr. Data from Annual rainfall trends (IMD) map for 1951-2011.*

5 *Increase indicate temperature rise above 1 degree Celsius and high increase is temperature above 3 degree Celsius. Data is from Annual Mean Temperature trends map (IMD) for 1951-2010.*

6 *Glacial retreat parameter has been further explained in the individual zones where the event is visible.*

7 *Refer to the water conservation practices to combat water scarcity.*

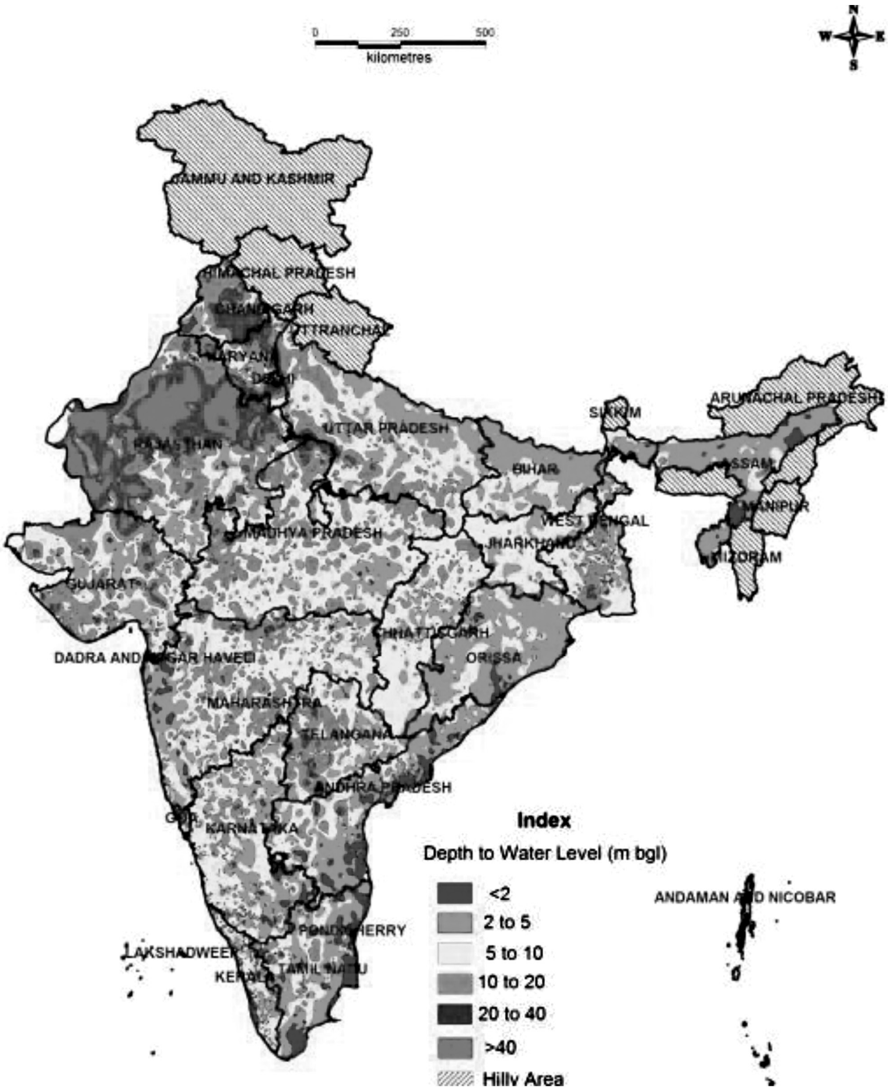
8 *High impact indicates zones where water scarcity is linked to climate change (by more than 50%), medium indicates water scarcity is linked to climate change (by 50%) and low indicates water scarcity is linked to climate change (by less than 50%) This is based on the subjective understanding.*

## Introduction

Water security is broadly defined as the capacity of a nation to guarantee the availability of quality water in a sustainable fashion. In this respect, water becomes an important security concern to high population density countries of South Asia. India, Pakistan, Bangladesh, Nepal (and China) account for half the world's total groundwater use. In spite of being a region surrounded by the Himalayas to the north, sea in the southeast and southwest and having perennial and well-connected inland rivers, South Asia is already a 'water-stressed' region. Because of this, water has emerged to be a critical driver of conflicts in the region. The report by the Asian Development Bank titled '*Asian Water Development Outlook 2013'* has labelled India's water security outlook for 2013 as "hazardous." India received the lowest water security index rating of 1 (on a scale of 5) by the report, along with countries like Bangladesh, Cambodia, Kiribati and Pakistan.

The issue of water security in India is lopsided. Water security in India can be understood by analysing the utilisation of the different types of water, namely, blue water (surface and ground water), green water (soil moisture) and grey water (waste water). Firstly, India suffers from an absolute water shortage. This means there is not enough 'safe' water to satisfy the rapidly increasing population of middle class. The total amount of usable water (both open source and groundwater) has been estimated to be between 700 to 1,200 billion cubic meters (bcm).[9] With a population of 1.2 billion (according to the 2011 census) India has only 1,000 cubic meters of water per person. In addition to this, around 60 per cent of Northern India's irrigated agriculture is dependent on ground water, as is 85 per cent of the region's drinking water. The World Bank predicts that India has only 20 years before its aquifers will reach the "critical condition" – when demand will outstrip supply.

9 *The figure is based on a report (2013) by The National Bureau of Asian Research. The institute concluded the figure based on an interview with Kirit S. Parikh, Chairman of Integrated Research and Action for Development (IRADe) and a former member of the Government of India's Planning Commission in charge of water and energy issues.*




Map 1: Depth of Water Level (January 2016)

*Source-Central Ground Water Board (January 2016)*

Secondly, water mismanagement is another reason that aggravates India's water crisis. In a country where half of India's population (600million) depends on farming and about two-thirds of the farm fields rely on rain as their primary source of irrigation, water management and distribution becomes crucial when rain fails.

| % of units | Safe | Semi-critical | Critical | Over-exploited | Salinity affected |
|---|---|---|---|---|---|
| 90+ | Arunchal Pr. Assam, Bihar, Goa, J & K, Jharkhand, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tripura, A&N Islands, Chhatishgarh, D & N Haveli | | | | |
| 75-90 | AP, Chhatishgarh, Gujarat, Kerala, WB | | | Punjab | |
| 40-75 | HP, Karmataka, MP, UP, Uttarakhnad, Lakshadweep, Puducherry | Daman & Diu | | Delhi, Haryana, Rajashthan, Daman & Diu | |
| 20-40 | Haryana, TN | MP, TN, Uttarakhnad, WB, Lakshadweep | | Karnataka, TN, Puducherry | Puducherry |
| 5-20 | Delhi, Rajashthan | AP, Chhattisgarh, Delhi, Gujarat, Haryana, Karnataka, Kerala, Maharashtra, Rajashthan, UP | Delhi, Haryana, Karnataka, Rajashthan, UP, Uttarakhand | AP, Gujarat, HP, MP, UP | |
| <5 | | Bihar, Jharkhand, Punjab | AP, Chhattisgarh Gujarat, Kerala, MP, Maharashtra, Punjab, UP, TN | Chhattisgart, Jharkhand, Kerala, Maharashtra | AP, Gujarat, Rajasthan, Orissa, TN |

Source : Central Ground Water Board, Mia of Water Resources

Table 1: Statistics on Groundwater availability in India

Thus even though the overt and the primary reasons for water scarcity in India may be dependent on climatic factors, the underlying and aggravating reasons are due to anthropogenic activities. The study aims to find this link between water insecurity (caused by scarcity) and climate change. Once the link is established, a map will be created to qualify how much role do climatic conditions play in causing water scarcity in India.

## Methodology

The study, "Water Security in India- Threat Mapping: Impact of Climate Change" is a pilot project to understand the various sociological, political and economic reasons for water scarcity in India, apart from climate change. Broadly a qualitative study, the report has divided India into 20 agro-ecological zones.An initial literature review has led to the identification offive contributing factors or parameters to water insecurity: ground water depletion, glacial retreat, rainfall, temperature, national water governanceand the civil society initiatives and water conservation practices. Keeping the agro-ecological zones as the base point, the report has studied the above factors in each ecological zone to understand the broad link between the causes of water scarcity and climatic variability. Following this, a table is compiled to measure each parameter as a step to the draw the larger map. The table in the beginning of the report summarises the study and the concluding column reflects the extent to which climate change affects the water insecurity in India.The table was prepared superimposing the primary data collected from the IMD, Central Groundwater Board and Ministry of Water Resources and secondary data from published research papers and data from World Bank and IFCC. Data collected during interviews of experts and field visit was compiled to measure the vulnerability index (approximately) of water security to climate change.

| Eco-system | Region | States represented | Eco-region | Soil type |
|---|---|---|---|---|
| Arid | 1.Western Himalaya<br>2. Western plain, Kutch and part of Kathiawar Peninsula<br>3. Deccan plateau | Jammu & Kashmir, HP<br>Gujarat, Rajasthan, Haryana, Punjab<br>AP, Karnataka | Cold arid<br>Hot arid<br>Hot arid | Shallow Skeletal Desent & Saline |
| Semi-arid | 4. Northern plain and Central Highlands including Aravalli's<br>5. Central (Malwa) Highlands, Gujarat Plains & Kathiawar Peninsula<br>6. Deccan Plateau<br>7. Deccan (Telangana) Plateau and Eastern Ghats<br>8. Eastern Ghats, TN uplands and Deccan (Karnataka) Plateau | Gujarat, Rajasthan, UP, MP, Haryana, Punjab<br>Gujarat, MP<br>Karnataka, AP, Maharashtra, MP<br>AP<br>Karnataka, TN, Kerala | Hot semi-arid<br>Hot semi-arid<br>Hot semi-arid<br>Hot semi-arid<br>Hot semi-arid | Alluvium- derived<br>Medium & Deep black<br>Shallow and Medium (with inclusion of deep) black<br>Red & Black<br>Red loamy |
| Sub-humid | 9. Northern Plain<br>10. Central Highlands (Malwa, Bundelkhand & Eastern Satpura)<br>11. Eastern Plateau (Chhaltisgarh)<br>12. Eastern (Chhota Nagpur) Plateau and Eastern Ghats<br>13. Eastern plain<br>14. Western Himalayas | Bihar, UP, Punjab<br>MP, Maharashtra<br>MP<br>Orissa, W. Bengal, Bihar, MP, Maharashtra<br>UP, Bihar<br>J&K, HP, UP | Hot sub humid (dry)<br>Hot sub humid<br>Hot sub humid<br>Hot sub humid<br>Hot sub humid (moist)<br>Warm sub humid (to humid with inclusion of per humid) | Alluvium- derived<br>Black & Red<br>Red & Yellow<br>Red & Lateritic<br>Alluvium-derived<br>Brown forest and podzolic |
| Humid-per humid | 15. Bengal and Assam plains<br>16. Eastern Himalayas<br>17. North Eastern Hills (purvanchal) | West Bengal, Assam<br>Arunachal Pradesh, Sikkim, W. Bengal<br>Tripura, Mizoram, Meghalaya | Hot sub humid (moist) to humid (inclusion of per humid)<br>Warm per humid<br>Warm per humid | Alluvium-derived<br>Brown and Red hill<br>Red and Lateritic |
| Coastal | 18. Eastern Coastal plain<br>19. Western Ghats & Coastal plain | TN, Puducherry, AP, Orissa, W. Bengal<br>Kerala, Goa, Daman & Diu, Maharashtra, Gujarat, Kerala | Hot sub humid to semi-arid<br>Hot humid per humid | Coastal Alluvium-derived<br>Red, lateritic and alluvium-derived |
| Island | 20. Island and Andaman-Nicobar and Lakshadweep | Andaman-Nicobar and Lakshadweep | Hot humid per humid | Red loamy and sandy |

Source: 1. *Fertiliser Statistics, 2010-11, The Fertiliser Association of India, New Delhi.*
2. National Bureau of Soil Survey and Land Use Planning (ICAR), Nagpur

Table 2: Agro-ecological Zones in India

## Water Security: Mapping Vulnerability

**Western Himalayas** (States: J&K, Himachal Pradesh)

According to the World Bank, India is the largest user of ground water in the world, after China. There is faster depletion of ground water than replenishment. But this is due to overuse in farming and meeting population (drinking water) demand. The replenishment is further staggered due to less rainfall and longer drought periods. The reason for this can be attributed to rise in temperature and climatic anomalies even though development driven industrialization and urbanization has aggravated thisphenomena. India extracted 251bcm of groundwater in 2010.

The overall contribution of rainfall to the country's annual ground water resource is 68% and the share of other resources, such as canal seepage, return flow from irrigation, recharge from tanks, ponds and water conservation structures is 32%. Due to the increasing population in the country, the national per capita annual availability of water has reduced from 1,816 cubic metre in 2001 to 1,544 cubic metre in 2011. This is a reduction of 15%.

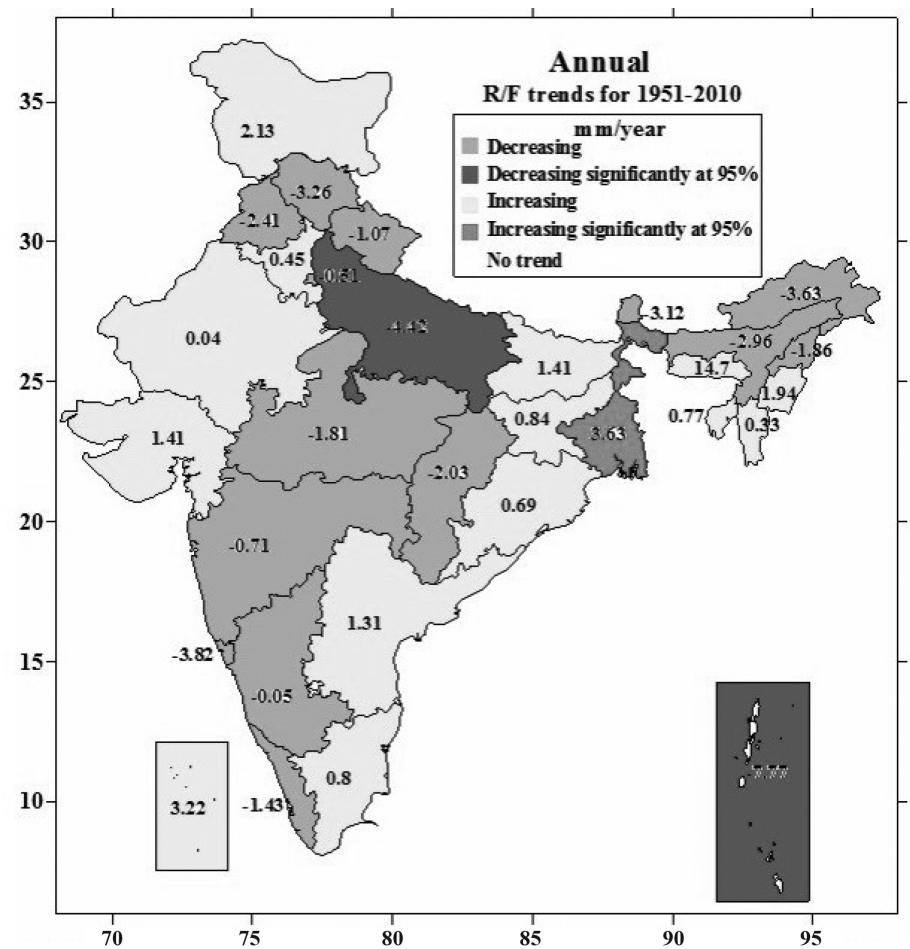
| Level of ground water development | Explanation | % of districts in 1995 | % of districts in 2004 | % of districts in 2009 | % of districts in 2011 |
|---|---|---|---|---|---|
| 0-70% (Safe) | Areas which have ground water potential for development | 92 | 73 | 72 | 71 |
| 70-90% (Semi-critical) | Areas where cautious ground water development is recommended | 4 | 9 | 10 | 10 |
| 90-100% (Critical) | Areas which need intensive monitoring and evaluation for ground water development | 1 | 4 | 4 | 4 |
| >100% (Over-exploited) | Areas where future ground water development is linked with water conservation measures | 3 | 14 | 14 | 15 |

Sources: Central Ground Water Board; PRS.

Table 3: Comparative status of groundwater level in past 20 years in India

The ecological zone of the Western Himalayas comprise of the states of Jammu and Kashmir, Himachal Pradesh. In Jammu, 27 million gallon of water is pumped out daily by 224 heavy lift pumps to meet the water requirement of the city. As of January 2016, the total numbers of active ground water wells are 261. According to a study conducted by the Public Health Engineering Department, out of the 22 major towns in the state, 14 are facing acute water crisis while five are on the threshold of reduced water supply.In the past decade, the ground water situation in the state is aggrieved by two factors-urbanization and changing rainfall pattern. Playing out simultaneously, the rapid development, without taking into account the ecological synergy, has in turn stressed the groundwater aquifers.

Analysing the decadal fluctuation in the depth of water level, the groundwater yearbook (Jammu and Kashmir) by the Central Ground Water Board, states that (2005-2015) in the month of May or the pre-monsoon month, a total of 92 wells (75.40%) have shown rise and 30 wells (24.59%) have shown decline in water level. In January, it is observed that a total of 81 wells (65.32%) have shown rise and 43 wells (34.67%) have shown decline in water levels. The fall in the water level, seen arithmetically is not huge. But when analysed in relative terms, keeping in mind the growing tourism and consumption by the housing sector annually, water crisis could become a matter of concern. The role of climatic factors in aggravating water security becomes a point of analysis when the gradual temperature rise and the simultaneous glacial meltdown




Map 2: Annual Rainfall Trends (1951-2010)

*Source: Rathore, L.S. et. al. (2013)/ IMD (2013)* are checked. In addition, there are problems of ground water contamination like iron (in Tertiary belt and in Kashmir valley) marshy gases (in shallow and deep aquifers of Kashmir valley) and fluoride (Doda district).

Rainfall activity over the country during 2015 as a whole was above normal. According to the 2015 annual climate report, the first half of the season (1 June to 31 July) the country received normal rainfall (95%of its Long Period Average (LPA) value), while during the second half (1August to 30 September) it received deficient rainfall (only 77%of its LPAvalue).

The State Centre on Climate Change in Himachal Pradesh, in its report analysing the monsoon trends from 1901 to 2012, stated that increasing trend during winter rains and summer rains in entire Himachal Pradesh was witnessed while no significant trend has been noticed in monsoon and post monsoon.

As per the Indian Network on Climate Change Assessment, the number of rainy days in the Himalayan region in 2030s may increase by 5-10 days on an average, with an increase by more than 15 days in the eastern part of the Jammu and Kashmir region. The intensity of rain fall is likely to increase by 1-2 mm/day. This prediction was made seeing the rise in temperature over the region. According to the Annual Climate Report (2015) by Ministry of Earth Sciences and IMD, parts of Himachal Pradesh, Jammu & Kashmir were warmer than the normal by more than 1 C.

The Kashmir valley has seen a rise in temperatures over the years, said G.M. Dar, associate professor (rural development), disaster management centre, J&K Institute of Management, Public Administration and Rural Development, Srinagar in an interview to Livemint. A report prepared for the state's department of ecology, environment and remote sensing in 2013 claimed average temperatures in the Kashmir valley had risen by 1.45 degrees Celsius over two decades. Is the temperature rise idiosyncratic of the region or in congruence with the global temperature rise, is a matter of future investigation. Unseasonal rains in March last year left a trail of destruction in the city of Jammu. The intense rain has led the Jhelum, which meanders through the city, to overflow.

| River | Origin | Catchment area ($km^2$) | Average annual potential in river ($Bm^3/yr$) |
|---|---|---|---|
| Indus | Mansarovar (Tibet) | 321289 + | 73.31 |
| Ganga | Gangotri (Uttar Kashi) | 861452 + | 525.02 |
| Brahmaputra Barak and others | Kailash Range (Tibet) | 194413 + | 585.60 |
| Sabarmati | Aravalli Hills (Rajasthan) | 21674 | 3.81 |
| Mahi | Dhar (Madhya Pradesh; MP) | 34842 | 11.02 |
| Narmada | Amarkantak (MP) | 98796 | 45.64 |
| Tapi | Betul (MP) | 65145 | 14.88 |
| Brahmani | Ranchi (Bihar) | 39033 | 28.48 |
| Mahanadi | Nazri Town (MP) | 141589 | 66.88 |
| Godavari | Nasik (Maharashtra) | 312812 | 110.54 |
| Krishna | Mahabaleshwar (Maharashtra) | 258948 | 78.12 |
| Pennar | Kolar (Karnataka) | 55213 | 6.32 |
| Cauvery | Coorg (Karnataka) | 81155 | 21.36 |
| Total | | 2528084 | 1570.98 |
| Other river basins of the country | | 248505 | 298.02 |
| Total | | 2776589 | 1869.00 |

*Source:* CWC (2002)

Table 4: Major River Basins and its catchment area

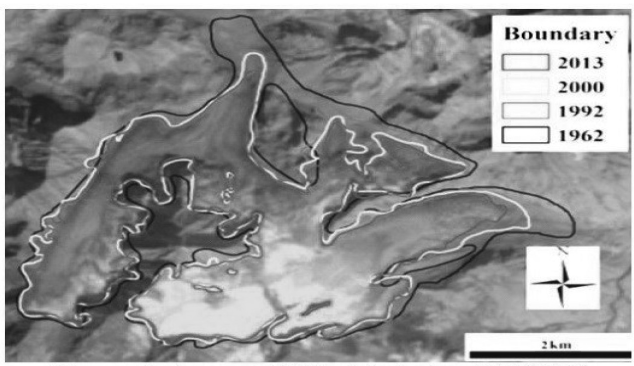
There are 12 major river basins in India with individual catchment area of more than 10Mha and a cumulative catchment area of 252.8Mha. The river systems are the major contributor (about 60%) to the surface water resource potential of the country. Jammu and Kashmir is fed primarily by Indus basin and then by Jhelum, Chenab and Ravi sub-basins. Unlike the Eastern Himalayan rivers which are mainly rain-fed, most of the water in the Himalayan rivers comes from snowmelt, which includes glacial melt. According to a research paper titled, 'Glacial retreat in Himalaya using Indian Remote Sensing satellite data' by the Department of Geology (Dharamsala) aerial extent of 466 glaciers which was estimated as 2077 sq. km in 1962 has reduced to1628 km2 in 2001–04. This is an overall 21% deglaciation.

| | | Glacier area (sq. km) | | | Volume (cubic km) | | |
|---|---|---|---|---|---|---|---|
| Basin | Glacier number | 1962 | 2001–04 | Loss (%) | 1962 | 2001–04 | Loss (%) |
| Chenab | 359 | 1414 | 1110 | 21 | 157.6 | 105.03 | 33.3 |
| Parbati | 88 | 488 | 379 | 22 | 58.5 | 43.0 | 26.5 |
| Baspa | 19 | 173 | 140 | 19 | 19.1 | 14.7 | 23.0 |
| Total | 466 | 2077 | 1628 | 21 | 235.2 | 162.73 | 30.8 |

Table 5: Basin wise loss of glacier area

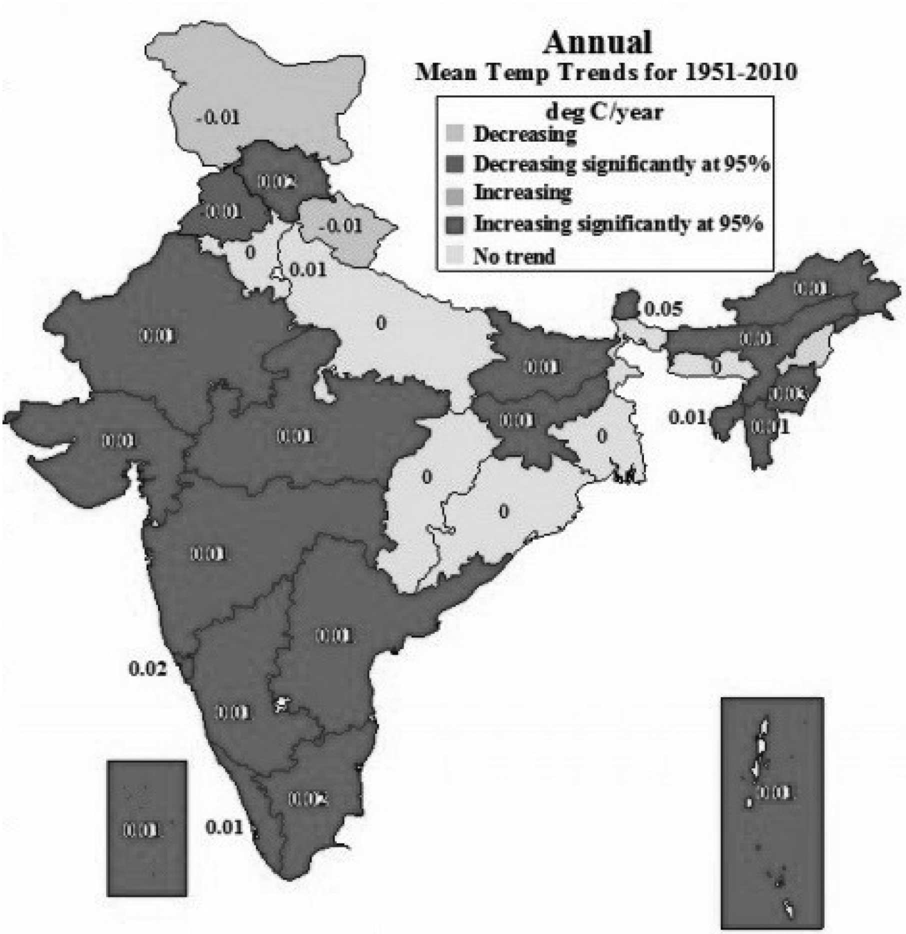
*Source: State Centre on Climate Change in Himachal Pradesh*

Measured by the Central Groundwater Board, the depth range of exploratory wells varies between 77 m bgl and 271 m bgl. Human encroachment and tourism activity has reduced the city's iconic Dal Lake to a sixth of its original size – from around 75 sq. km to 12 sq. km. Similarly the Wular Lake has shrunk from 159.74 sq. km to 86.71 sq. km from 1911 to 2007. From 1911 to 2004, Srinagar lost more than 50% of its water bodies because of unplanned urbanization. Srinagar lies cradled in the bowl-shaped Kashmir valley, surrounded by mountains. The city is teeming with 1.5 million people. In Himachal Pradesh, the state government has approved detailed project report of about 139 crore to construct 956 rain water conservation structures. While there exist isolated and individual efforts in building water harvesting campaigns, these are not enough to build a collective effort. In Ufrenkhal region of Uttarakhand, villagers successfully transformed a dry ravine into river by digging small percolation pits on slopes and planting grass immediately downhill of the pit to protect the edge.




*Changes in the extent of Kolhoi glacier from 1962-2013*

| S.No. | Year | Total extent km² | |
|---|---|---|---|
| 1 | 1962 | | 13.67 |
| 2 | 2013 | | 10.92 |
| Loss in spatial extent | | (Ref: DOI:10.1657/AAR0014088) | 2.75 |

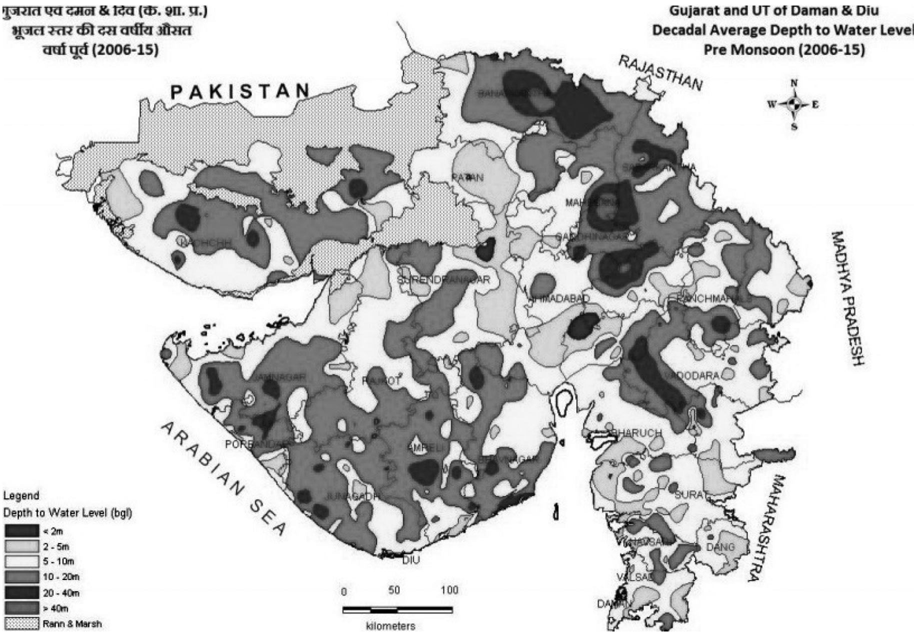



Map3: Annual Temperature Trends

*Source: Indian Meteorological Department (2013)*

**Western plain and Kutch Peninsula (**Gujarat, Rajasthan, Haryana and Punjab)

The ground water level in Gujarat, has increased by 67 per cent as on May 2014. This was due to the rise in use of Narmada canal for drinking and irrigation purposes. According to the groundwater handbook (2015-16) by the Central Ground Water Board, over 4 meters fall has been observed in most of the districts in Gujarat including Ahmedabad, Banaskantha, Vadodara, Amreli, Rajkot and Kutch. The decadal average water level map for the period May 2006 to May 2015 reveals that the decadal average water level in Gujarat has remained close to 2 to40 m bgl.




Map 4: Decadal depth of groundwater level

*Source: Groundwater Handbook (2014-15)*

It should be noted that drinking water, per capita fresh water availability is almost 40 per cent less in Gujarat compared to the national average. While fresh water availability is 1545 cubic meter per capita per person in India, it is just 945 cubic meters in Gujarat. The shallow water levels of less than 5 mbgl were observed along the coast, Rann of Kachchh. The quality of ground water is inferior along the Rann of Kutch coastand in the low-lying saline tract of Saurashtra. The deterioration in ground water quality here is due to frequent seawater ingress. In the state, out of total water availability 80 per cent goes to irrigation, 10 per cent to domestic and rest 10 per cent to industries. Haryana is considered the rice bowl of India with the largest paddy-growing areas. But the groundwater level is dropping by 21cms every year, resulting in the increase of dark zones. The groundwater level has dropped by eight metres in the last five years. In 2015, the International Journal of Enhanced Research in Educational Development published a report stating that Haryana, in its sixth drought in 11 years, is facing serious environmental degradation post Green Revolution era that made the state self-sufficient around four decades ago. A study by the National Academy of Agricultural Sciences in 2011 reads, “Water-table in 82 per cent area of Punjab and 63 per cent of that in Haryana has gone down substantially.” The study also mentions, “In Haryana, only

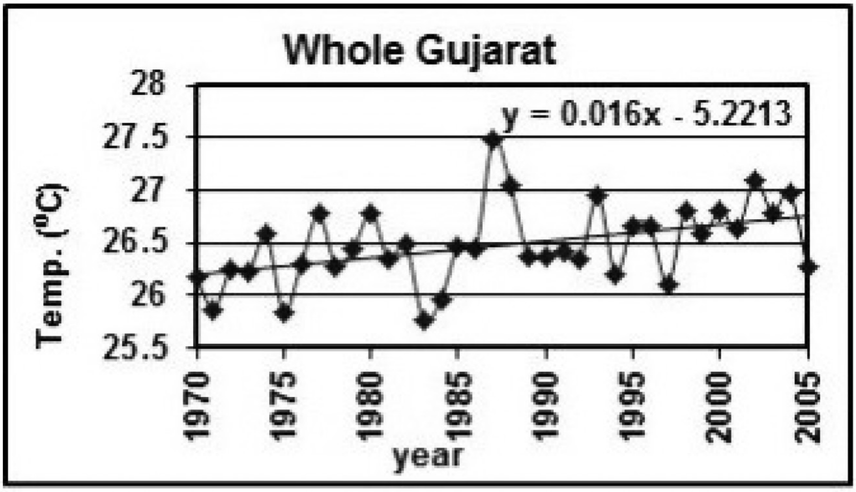
37 per cent of the water is exploited within the safe limits while 14 per cent over-exploitation has reached a semi-critical to a critical stage."According to a report published by Central Groundwater Board, Punjab extracts 145 per cent water from ground against an average 100 percent recharge and Haryana extracts 109 percent. Reduced rainfall has added to the rising water insecurity. As per the agricultural department, Haryana receives an average rainfall of 354.5 mm. It is not enough for the natural recharging of the groundwater. This has given rise to severe drinking water distressing the two states.

In the journal *Water*, a report titled, 'Understanding Groundwater Storage Changes and Recharge in Rajasthan (India) through Remote Sensing' entails a similar tale for the state. But Rajasthan is in better shape when it comes to addressing water insecurity, due to government and civil society initiatives. According to the report, Rajasthan only possesses 1.2% of the total surface water and 1.7% of the groundwater. The state is heavily dependent on groundwater for both irrigation and drinking water. During the 1970s and 1980s (the era of Green Revolution) there was widespread use of groundwater and the pressure is further increasing due to population growth and industries. About 80% of the State has witnessed groundwater depletion.

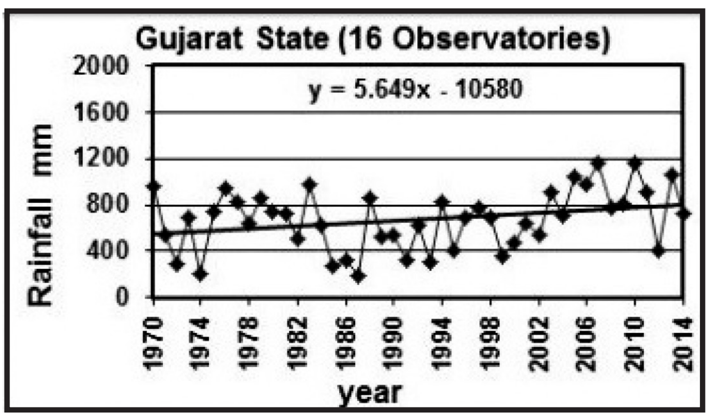
In Gujarat, the average rainfall for 2015 is 712 mm, which is 30 percent less than the decadal average. Gujarat is one of the frequent drought prone states of India. Several consecutive droughts have been experienced in last 20 years and 1986-88 was the longest and the most severe. Monsoon rainfall over the state shows a statistically significant increasing trend with a change of 56 mm/ decade and over the semi-arid region the increase is much more, about 65 mm/decade.

There is a simultaneous increasing trend in temperature over the arid region of the state, but monsoon rainfall doesn't show any increase in terms of intensity as well as frequency. Thus, rainfall doesn't bring much respite as the temperature increase is felt strongly. The average recorded rainfall for the entire state of Rajasthan from 2004 to 2013 was 572 mm.

According to the report titled 'Trends in intense rainfall events over Gujarat (India) in the warming environment using gridded and conventional data' in the International Journal of Applied Environmental Sciences, the period 1991-2014, recorded a temperature increase at a rate of 0.100C/decade. A shift (increase) in annual temperature of 0.910C is observed between 1931-1990 and 1991-2014. For Gujarat, the increasing trend in the annual mean temperature for the period 1971-2006 is statistically significant and it is about 0.160C/ decade.




Graph 1: Temporal variation of the mean annual temperature over



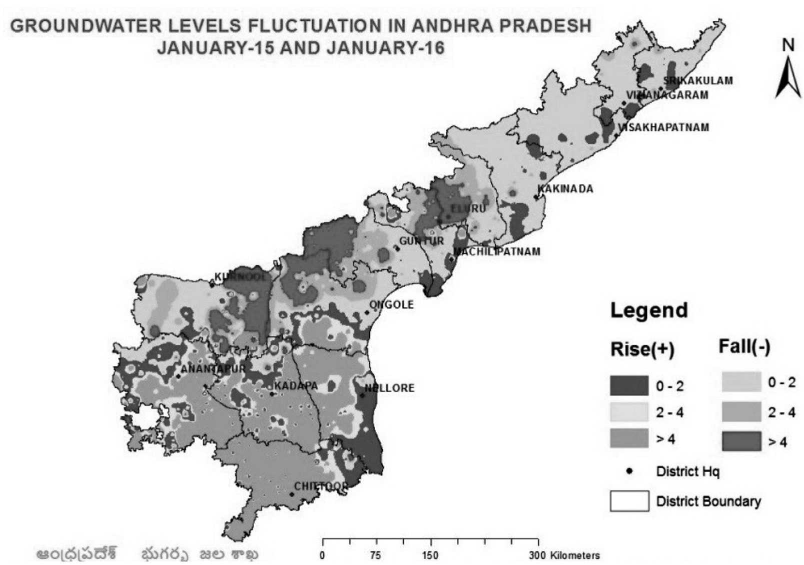

GujaratGraph 2: Temporal variation of the mean annual monsoon over Gujarat

*Sources: IMD (2014)*

In this ecological zone, given the soil texture, arid to semi-arid climate, the problem of water security is acute. But except in the state of Punjab and Haryana, the stress has been considerably overcome with the involvement of government and several civil and individual actions. In January 2000, the Gujarat government launched the Sardar Patel Participatory Water Conservation Programme wherein 25,000 check dam was built by the people themselves. On account of this, the rate of groundwater recharge and availability of drinking water has increased. One such village is Padodar in Gharda tehsil of Bhavnagar district. In the past two years, no government water supply reached the village. Yet, in September 2000, there was ample water. It is recorded that between March 17 and June 17, the villagers built 51 check dams. Similarly, in Rajasthan, the Aakar Charitable Trust by Amla Ruia, has helped in the construction of 200 check dams in 100 villagesfor over 2 lakh people. The most famous tale of water conservation is by Rajendra Singh called the waterman of India. By helping the villagers build mud dams (*johads*), today, there are nearly 8,600 *johads*to collect water. This has provided water to over 1,000 villages across Rajasthan.Farmers of the Saurashtra and Kutch region revived the once perennial Meghal River by building check dams to store water all throughout the year.

## **Deccan Plateau (**Andhra Pradesh and Karnataka)

Even though, Andhra Pradesh has 40 rivers, 12 of them being inter-state, there is a gap between the demand and supply of water to all sectors such as irrigation, domestic and industry. According to Andhra Pradesh government estimate, the total water utilisation in the state in 2015 was 29.18 BCM of which 96 per cent was for irrigation and only 0.6 per cent was by industries. The total domestic drinking water use is about 3.25 BCM. It has been estimated that water consumption across these sectors is expected to increase by at least 50 per cent from the current 29.18 BCM to 42.68 BCM. In addition, with population growth and urbanisation, the demand and supply gap in water distribution is bound to widen.




Map 5: Andhra Pradesh Groundwater level scenario

*Source: Central Groundwater Board (2016)*

The groundwater consumption is also dire. According to the central groundwater board report, the average groundwater level for the state in January 2016 was 9.74 m., where as it was 10.86m.during the same period in the previous year. In 2015, the Vempalle mandal of Kadapa district in AP has recorded 114.10 m BGL. This is the deepest water table in the state. The reasons as projected were overtopping of the third aquifers by drilling borewells to a depth of more than 1,000 feet. Second, is the geological formation of the Vempalle area where recharging is inherently poor. Usually, when limestone is on the top and shale is below, the ground water will be on the top. But in the most of Deccan plateau region, limestone layers are deep below the shale and on account of this water is available only after a certain depth. With this geomorphologic setup, deficit rain fall has created a longer dry spells thereby inducing water scarcity in the central Deccan belt.

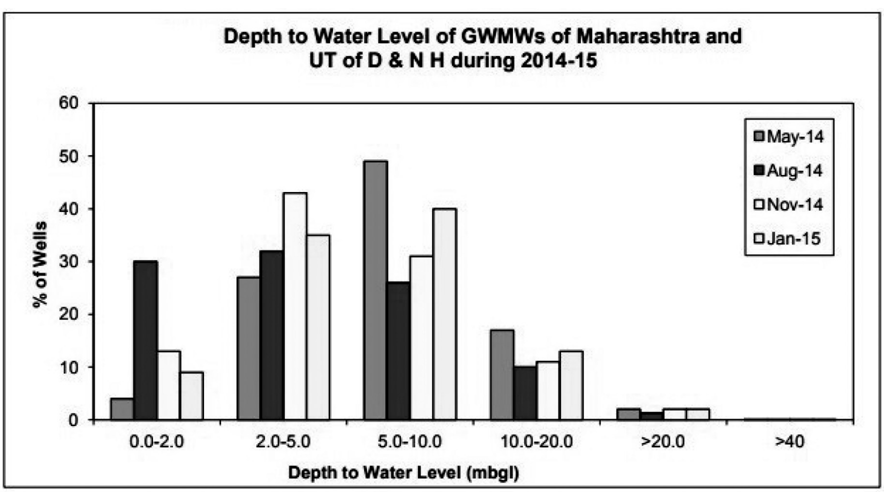
According to the IMD report, Andhra Pradesh as a whole received 3.6 mm rainfall as against the normal rainfall of 8 mm thus records55% less rain during January 2016.Similarly in 2015 Karnataka recorded 22 percent rainfall deficit during monsoon. Speaking on the rainfall deficit, chief minister of Karnataka gave the estimation that the state records only 50 TMC of water (as of 2016). Nearly 40 TMC of water will be needed for activities other than drinking thus just 20 TMC is left to fulfil the drinking needs of the whole state.

There are seven river systems in the Karnataka namely Krishna, Cauvery, Godavari, North Pennar, South Pennar and Palar. According to an Indian Express report, the country's southern tip — the old Mysore region (south interior Karnataka), Kerala and Tamil Nadu — has had an approximately 25 per cent below-average rains this year. This comes on top of rainfall deficiency that amounted to over 35 per cent last year. This new statistics has replaced Maharashtra as the new epicentre of drought, with back-to-back rainfall failures similar to what Marathwada experienced in 2014 and 2015. This rainfall deficit coupled with fall in groundwater levels has intensified the inter-state water sharing issue. Last year September saw a major stand-off when the Karnataka government, on account of a Supreme Court order, was forced to release water from its reservoirs on the Cauvery river basin to the Mettur dam across the border in Tamil Nadu. It triggered violent protests by pro-Kannada groups who contended that there was hardly any water in the Krishna Raja Sagara reservoir. Kabini and Harangi are at 40 percent capacity while Krishna Raja Sagara and Hemavathy have only between 15-20 percent of their capacity. Rising temperature has also been a concern in the southern peninsula. Severe heat wave incidences over the south peninsula and eastern parts of the country took a toll of over 1400 lives from the states of Andhra Pradesh and Telangana during May and June. An analysis of the meteorological measurements of temperature for Karnataka has shown a steady warming trend in both the minimum and maximum temperatures.

There are several government initiatives in place like the irrigation water projects over the Papagni near Anantapur in Andhra Pradesh, the Andhra Pradesh Water, Land and Trees Act, 2002, wherein construction of bore well is banned in regions with groundwater level below 20mts and the Neeru Meeru programme. The Neeru Meeru programme that aimed to desilt old tanks in 3,348 villages is a failure. This is because, the way the programme has been planned, has left room for contractors and engineers to exploit many villagers. In Karnataka, rain water harvesting as a measure to adapt to water insecurity has taken ground. In addition, several impact land treatment, intervention-drainage treatment and restoration of tanks have been initiated. Still in its nascent stage, RWH is yet to translate into conclusive solutions especially in urban Karnataka.

## **Deccan Plateau (**State: Maharashtra)

According to a report by the Maharashtra Groundwater Surveys and Development Agency, the groundwater level in 60 per cent tehsils of Maharashtra has depleted by a minimum of one metre. The report further estimates that a total of 2,130 villages in 72 tehsils, where there was a rainfall deficit in a range of 0-20 per cent in 2016, have shown groundwater depletion of more than one metre.




Graph 3: Groundwater level in Maharashtra during 2014-15

*Source: Groundwater Yearbook of Maharashtra and UT Dadra and Nagar Haveli (2014-15)*

In addition, the 17 big reservoirs in the state are left with just about 2 BCM of water, which is 14% of their total capacity. Data from the Central Water Commission (CWC) show that water levels in Maharashtra's reservoirs was just over 30% of full capacity in the first week of January this year. Between January and May this year, water levels in all 91 big reservoirs in the country, including the ones in Maharashtra, almost halved from a cumulative 44%. According to same report, the basins of the Tapi, Krishna and Godavari, all of which lie partially in Maharashtra, have very little water compared to normal levels.

From a departure of normal monsoon rainfall trend, as per the IMD, rainfall in 34 districts of Maharashtra, especially Marathwada regions, have received deficient rainfall with negative departure of -42%. When the decadal fluctuation of ground water levels was checked, the Groundwater Yearbook reported that the long-term decline in water levels may be due to poor saturation of aquifers and may be due to large-scale developmental activities for which the ground water resources are frequently exploited.

Around 82% of the state is made up of hard rock or Deccan trap basalt, this has a very low water storage capacity. In addition to this, a look at the rainfall pattern shows that it is not uniform and there is considerable regional as well as annual variability. Maharashtra experiences extremes of rainfall ranging from 6000 mm to less than 500 mm. The Western Ghats receive more than 6000 mm of rainfall while the plains receive 2500 mm of rainfall. The rainfall decreases towards eastern slopes and plateau areas where it is less than 500 mm.

The rainfall then again decreases towards east i.e in the direction of Marathwada and Vidarbha to around 1500 mm. Thus, the Madhya Maharashtra sub-division is the region of the lowest rainfall in the state and is almost always in the grip of water scarcity and droughts. As high as ninety-nine talukas in the state are chronically drought affected.

Maharashtra is one of the few states that enacted the Maharashtra Groundwater (Regulation for Drinking Water Purposes) Act 1993. However, the law is silent on issues such as how much water may be withdrawn for irrigation. In 1999, the Chitale Commission reviewing the drought situation in the region had put forth the concept of looking at groundwater use in totality as that used for drinking as well as irrigation, with deeper groundwater to be used for drinking purposes while the annually replenish able one for irrigation. Post this recommendation, the Maharashtra Water and Irrigation Commission had recommended that it is necessary to register wells, bore wells and tube wells and to consider and estimate groundwater and surface water together and that too on a watershed/sub basin basis. Periodic estimation of the groundwater level fluctuations was taken into consideration by the Maharashtra Groundwater Surveys and Development Agency. In addition, there exist a government-sponsored watershed programme called the 'Jalyukta Shivar Abhiyan' that has begun in over 6,000 villages and aims at making 5,000 of them free of water scarcity. Acute water scarcity in the belt has resulted in failure of agriculture. In a public statement the State's Relief and Rehabilitation Minister Eknath Khadse said over 1,000 farmers have committed suicide last year.

In Latur, the villagers have revitalised 2.5 km out of 7 km of the nullah in the village, spending their own money. The Kumar Sahwas a residential complex in the foothills of Pune has successfully attempted to divert all the rainwater flowing down from the roads to recharge bore wells after passing the water through soak pits and sand filters. These government and civil society initiatives have helped in combating the issue of water security in the region. It should be noted all these initiatives are short term and time bound mitigation initiatives rather than long term plans directed at tackling the anthropogenic (developmental activities) causes to water security.

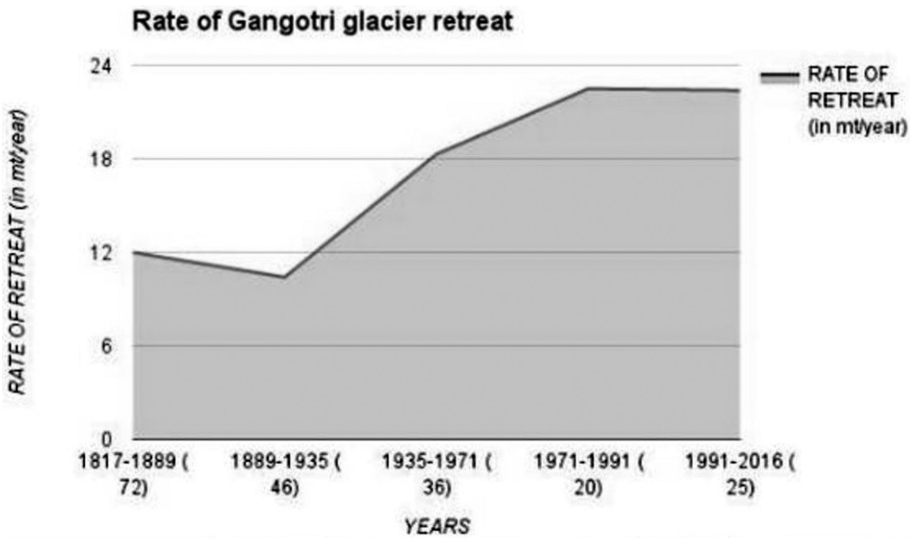
## **Northern Plains (**States: Bihar)

Bihar is highly flood prone during monsoons and drought prone in the pre monsoon seasons. While North Bihar in general is highly flood-prone, South Bihar is highly drought prone. In the (relative) absence of state level climate models and/or vulnerability studies, as well as low community awareness, Bihar is potentially more sensitive and vulnerable to the climate change and its impact. In addition, the state is also prone to earthquake. Located in the high seismic zone perched on the boundary of the tectonic plate joining the Himalayan tectonic plate near the Bihar-Nepal border and having six subsurface fault lines penetrating through its Gangetic planes in four directions, Bihar is vulnerable to the disaster caused by earthquake of near maximum intensity.

According to the Groundwater yearbook Bihar (2015 - 2016), for the period from May 2014-2015 the fluctuation of ground water level of 441 monitored centres indicate rise in water level in 181 well sand fall in water level in 255. The decadal mean of groundwater fluctuation from January 2015 to 2016 (post monsoon period) indicate that in 24% of the monitored centres, rise in water level is recorded and remaining 76% centres fall in water level has been observed. This indicates that the aquifer recharge is heavily dependent on rainwater and a weak monsoon for the past few years has affected the groundwater levels as well. A look at the rainfall pattern indicate that in the year 2015 the state received only 742.3 mm rainfall which is about 28% less than normal monsoon.

The northern plains/Terai region of Bihar is highly flood prone. Several reports have indicated the rising river water in Mahananda, Kosi, Gandak, Bagmati, Burhi Gandak and Kankai rivers in Nepal and a cumulative high intensity rain for a shorter period (cloudburst) as the reason for frequent landslides and flash floods.As detailed in the Vulnerability Atlas of India, 27 districts in Bihar are fully affected by high-speed winds of 47 m/s intensity. In addition to intensive rain, melting of glacier is also seen one of the many factors behind rising river water and subsequent flood. It has been estimated that the Gangotri glacial (source of Ganga) have retreated by over 3 kilometres since 1817. Though a three-kilometre retreat over two centuries might seem negligible but the rate of retreat has increased sharply since 1971. Currently as estimated by the National Institute of Hydrology (NIH), Roorkee, the rate of retreat is 22 metres per year.

Winter precipitation feeds the glacier. About 10-15 spells of winter snow as part of western disturbances maintains the glacier. But last year Gangotri received very little snowfall. According to an interview in *The Hindu* Professor Manohar Arora, scientist at NIH, saidmore rain and slight temperature has been observed over the Gangotri, both of which transfer heat on to the glacier, thereby warming it. Small lakes have formed on top of the glaciernear Tapovan. As an eminent conservationist and mountaineer Harshwanti Bisht said, it was the blast of one such glacial lake in Chorabari that led to the June 2013 flood disaster in Kedarnath. If expert opinion and research work are to be believed then the frequent floods in Bihar cannot solely be attributed to rain and river overflow. A particular attention needs to be given to glacier retreat as well. Disaster gets exacerbated by certain other factors like high population growth, environment degradation, sand casting and changes in land use due to sand casting. However, most of the disaster management measures are aimed at mitigation rather than prevention.




Graph 4: Gangotri Glacier Retreat

*Source: The Hindu (2016)*

Taking into account the scorching heat and depleting groundwater level (especially in south Bihar), urban development and housing department of Bihar government has decided to set up a control room at the secretariat. People can lodge their grievance related to water crisis on 0612-2210000. This apart certain individual civil society initiatives like in Gaya Bihar: Magadh Jal Jamaat a group aims at reviving *ahar pyne*. A traditional water conservation and disaster management mechanism, *ahar pyne* involves construction of diversion channels to lead the floodwaters of the rivers into a reservoir with embankments on three sides.

## **Central Highlands (**States: MP and UP)

Comparison of November 2015 water levels with that of May 2015 shows that there is a rise in the ground water level in about 84.54% of the wells due to monsoon recharge and 15.46% of wells show decline in water level (Groundwater yearbook -2015-16- Madhya Pradesh). Rise in the order of 0-2 m is seen in about 37.33% of wells in the state. 26.47% of wells show a rise in the order of 2-4 m. However a pre-monsoon report by the Central Ground Water Board on the groundwater scenario stated that 68% of the wells monitored in Madhya Pradesh have recorded a decline in groundwater levels, as compared to 2014.

When the groundwater level of 2015 is compared to the decadal mean

(2005 -2014), 48% of the wells show a decline in water level. According to a report in Hindustan Times, an increasing demand of water for human consumption, agriculture and industry, coupled with erratic rainfall has led to the indiscriminate exploitation of groundwater. In the same report, Lokendra Thakkar, state coordinator of the Climate Change Knowledge Management Centre on Climate Change, said over 90% of the water used for drinking and domestic purposes in MP. According to the Groundwater Yearbook 2015 estimates 33.52% wells have nitrate concentration above permissible limit.

The study, "Climate Change in Madhya Pradesh: Indicators, Impacts, and Adaptation," done jointly by IIT-Gandhinagar and IIM-Ahmedabad says that with rise in temperatures, the "frequency of severe, extreme, and exceptional droughts in the state" will also increase. In UP, there is a declining trend in 51.4% of the monitoring wells covering over 10 years. Apart from groundwater, the states depend on river water for drinking purposes as well. Catchments of many rivers of India lie in Madhya Pradesh. The northern part of the state drains largely into the Ganga basin and the southern part into the Godavari system. The Narmada and Tapi rivers flow from east to west.

Data from the agriculture department of MP show that the state has had deficit rainfall almost every year since 2002. 2013-14 was only year when above average rainfall was recorded. There is a definite trend of increase in events like drought, heavy rain, hailstorms, etc," concluded the Bhopal meteorological centre director Anupam Kashyapi in the same report. It was observed that the long-term monsoon precipitation for the state of MP was stable for the period of 1951-2013. However, it can be noticed that monsoon season precipitation declined slightly during the recent decades. During the monsoon season, the five most deficit years occurred in 1979 (597 mm), 1965 (610 mm), 2007 (696 mm), 1966 (702 mm), and 2009 (725 mm). On the other hand, the five most surplus years during the monsoon season occurred in 1961 (1372 mm), 2013 (1307 mm), 1994 (1303 mm), 1973 (1243 mm), and 1990 (1167 mm). It was observed that the state experienced four severe droughts during the period of 2000-2010 highlighting that the drought frequency has increased during the recent years.

On the other hand, UP has received 189.8 mm rainfall which is 102.2% of the 185.6 mm normal rain after three parched years. Sixteen districts have deficient rains. Rainfall in the state is largely uneven as out of 71 districts of Uttar Pradesh, 42 districts received deficient, 26 received scanty, two districts received normal and only one received 20 excess rainfall (IMD report 2014). According to the study, "Climate Change in Madhya Pradesh: Indicators, Impacts, and Adaptation," there is a sharp increase in the frequency of the number of hot days during the period of 1951-2013. The number of hot days has greatly increased after 1990 in the state of MP. So have the frequency of heat waves. The year 1988 experienced the most number of heat waves and was also the year with a severe drought in the region.

In Madhya Pradesh, post the Bundelkhand drought, a new act has been enacted wherein; no new hand pump will be dug without maintaining minimum distance between two handpumps. Around 2.13 lakh riser pipes were also constructed to ensure constant supply during the three crucial summer months. However since last 15 years all state sponsored schemes meant for water conservation have not shown good results. During Congress regime in 2001, government initiated rain water conservation on a big scale and launched the Rajiv Gandhi Watershed Development Mission. As this watershed development was restricted in certain areas, the state government took a new programme of conservation that could reach out to all districts and named it Paani Bachao Abhiyan. To ensure rights to village panchayats to own their resources, another programme Ek Panch Ek Talaab was started. This was to ensure every member of the village, block and district panchayat becomes responsible for reviving or constructing a pond or tank. A similar programme in Malwa region, Malwa Jal Sammelan (water conference) was also organised. However, these programmes lacked the intended reach and with acute shortage came corruption and water mafia that deterred the implementation.

During the BJP regime, Balram Talab Yojana was launched to increase the ground water-table which was later restructured as Atal Talab Yojana. Under the scheme a subsidy of 25% up to a maximum of Rs50,000 would be provided for constructing a large tank to augment irrigation potential. Corruption charges galore in disbursing funds for the projects. In UP, 400 water tankers have already been delivered by the Uttar Pradesh government to equitably distribute water among these regions reeling under water shortage.

In addition, the ‘100 Pond Restoration Scheme’ has been launched by Akhilesh Yadav aimed at improving land-irrigation in the drought affected regions. In Lalitpur (UP), one of the worst drought affected region, had only one pump for around 600 people. Similarly Bundelkhandis starved of water and food. According to the 2011 Census, there are 18.3 million people living in the 13 districts that make up this region spread across Uttar Pradesh and Madhya Pradesh. But given the current drought propensity, migration has increased to about 60-65 per cent, against 30-40 per cent in previous years. Few isolated efforts have been taken by the communities to combat water insecurity. Such as, the women of Langoti village in Khandwa district of Madhya Pradesh have successfully dug a well on their own after the gram panchayat refused to help them.

## **Eastern Ghats (**States: Tamil Nadu and Kerala)

The 2011 Census shows that 65 per cent of rural and 59 per cent of urban households have wells in Kerala. This density of wells is the highest in the country and is higher in the coastal regions. In addition, Kerala has recorded 45 per cent less water in its dams compared to last year According to the Kerala irrigation department, in 20 big and small dams under the department, water storage stands at a pathetic 535.74 mm3. On the same day last year, the storage stood at 978.36 mm3, meaning the dams had held 45.24 per cent more water then. These figures indicate that as the water in the reservoirs are reducing the construction of wells are simultaneously increasing water woes in the state.

| Year | Population (crores) | Per capita ground water availability (Litre/day) |
|---|---|---|
| 1901 | 0.64 | 3,095 |
| 1911 | 0.71 | 2,790 |
| 1921 | 0.78 | 2,539 |
| 1931 | 0.95 | 2,085 |
| 1941 | 1.10 | 1,801 |
| 1951 | 1.35 | 1,467 |
| 1961 | 1.69 | 1,172 |
| 1971 | 2.13 | 930 |
| 1981 | 2.45 | 780 |
| 1991 | 2.95 | 672 |
| 2001 | 3.36 | 590 |

Table 6: Per capita groundwater availability in Kerala

*Source: Devi, I.P. (2012)*

In South Kerala, the Vamanapuram River in Thiruvananthapuram, for instance, has recorded low water storage. The water is down so much that water supply scheme dependent on it may have to be halted in the absence of summer rainfall. Similarly, tubewell-based irrigation in Alappuzha is hit on account of depleted groundwater levels. Thalassery and Koothuparamba blocks in the district have been categorised as semi-critical in a recent report by the Ground Water Department. The situation in central Kerala may be little better. Water levels in Periyar and Chalakkudy rivers have dipped but not to the extent as the Vamanapuram River.

On account of low water in the river basins as well as dipping groundwater levels, drought has severely hit in many areas in Kerala. The Bharatapuzha and Manalippuzha, the main water sources for Thrissur district is most hit. In Palakkad, schemes dependent on Bharatapuzha, Kunthipuzha and Thoothapuzha are facing a crisis. About 50 % wells are showing decline in water level, out of which 37 % wells are showing decline in water in the range of 0-2 m. The groundwater potential of Kerala is limited because 88 per cent of the total geographical area of the state is formed of crystalline rocks devoid of any primary porosity.This year, with 29.1 per cent deficiency in rainfall, Kerala's power production also would be affected due to fall in rainfall. As the chief minister of Kerala, Vijayanin a public statement said, the shortage was 36 per cent in Idukki, 59 per cent in Waynad and 35 per cent in Thiruvananthapuram, where major hydel power projects were situated. There is an increasing trend of drought years. Looking at the long-term rainfall trend of Kerala, Tamil Nadu and Pondicherry there was no abrupt fluctuation up to 2000. In Kerala, the fluctuation occurs for certain period of interval that is still going on.This is because the consistent departure of rainfall from the normal course for 61 years has led to the formation of severe drought like condition. Along with it there was simultaneous rise in temperature. The report in 'Kerala Climate', a publication of Institute of Climate Change Studies, has attributed this temperature rise to the rise in temperature in the Indian Ocean.

The district office of the Ground Water Department in Kerala has constructed four groundwater recharge structures in the past five years, including those at Navodaya Vidyalaya, Chendayad, and Kendriya Vidyalaya, Payyanur. As part of the 'Haritha Keralam' project 15,022 water bodies have been recharged and 3931 public wells dug. Besides this, 3855 new pounds were built and 13247 ponds across the state were rejuvenated. Mazha Polima,' a project which seeks to create public movement on recharging of open wells through rain water harvesting and was successfully launched in Thrissur district as part of National Rural Employment Guarantee scheme.In the Thrissur, Mazhapolima district of Kerala in 2008 an initiative was launched for rain water harvesting. Similarly, a group of 20 women in Kalikavu village near the Malappuram district of Kerala (collaborating under the National Rural Employment Guarantee Scheme) have dug over 100 bore wells in a year to end water scarcity in this region.

## Case Study: Chennai and Water Security

Located on the leeward east coast, Chennai has always been water starved. But over the past few years, along with chronic water shortage, the city/the state is reeling under frequent high-intensity cyclonic storms, heavy rains and floods. In a city surrounded by three major waterways — Cooum, Adyar and Buckingham canal (now mostly reduced to sewage carriers) water scarcity is ironic. This reflects the degenerating impact of urbanisation over the city's natural resources. The Chennai deluge in December 2015 and then the Cylone

*Vardah* in the second week of December 2016: a question has often been asked as to whether these extreme events are an effect of climate change? According to the statistics by the IMD, the death toll due to two major flood and rain related incidents during 9 November to 2 December 2016 was nearly 350 in Tamil Nadu. The cyclone has affected around 17.64 lakh people in Tamil Nadu. The answer to the above question (after interviewing experts at MIDS, M S Swaminathan Research Foundation and vetting several reports) is No.

**Chennai Metropolitan Water Supply & Sewerage Board**

**STORAGE AS ON 22.8.2017**

**WITH REFERENCE TO MEAN SEA LEVEL**

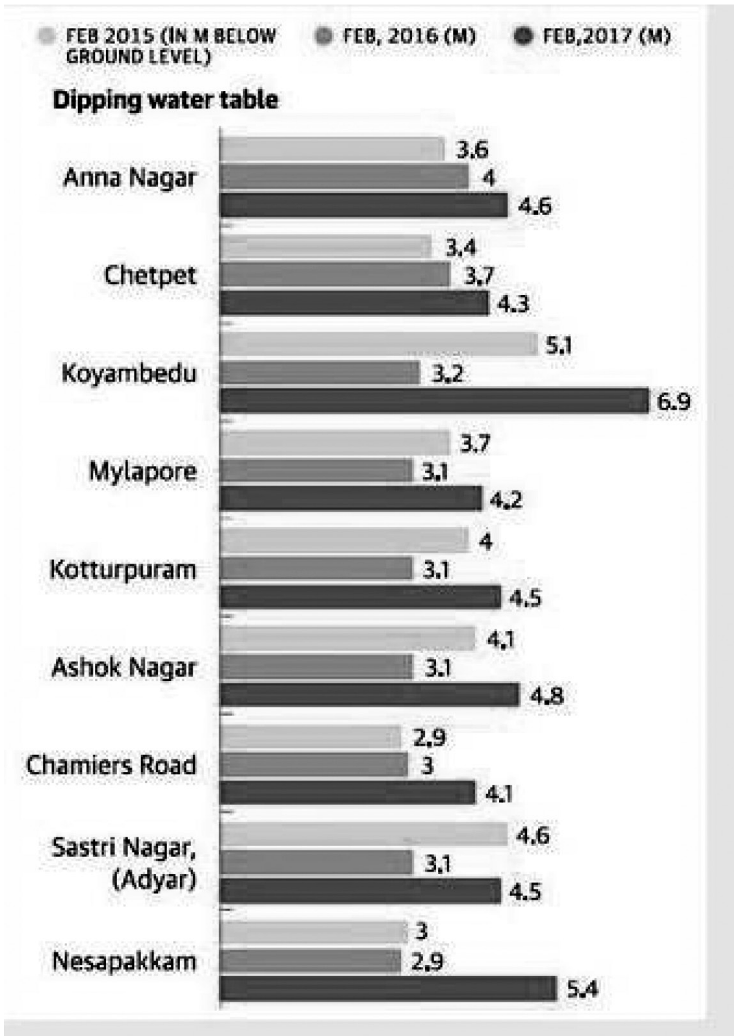
|  RESERVOIR | Full Tank Level (ft.) | Full Capacity (mcft) | Level (ft) | Storage (Mcft) | Inflow (cusecs) | Outflow (cusecs) | Rainfall (mm) | Storage as on same day last year (mcft) |
|---|---|---|---|---|---|---|---|---|
| POONDI | 140.00 | 3231 | 118.70 | 22.00 | 0 | 1 | 0.0 | 609.00 |
| CHOLAVARAM | 64.50 | 881 | 0.00 | 11.00 | 35 | 0 | 2.0 | 72.00 |
| REDHILLS | 50.20 | 3300 | 24.39 | 46.00 | 52 | 5 | 1.0 | 804.00 |
| SUB TOTAL | - | 7412 | - | 79.00 | - | - | - | 1,485.00 |
| CHEMBARAMBAKKAM | 85.40 | 3645 | 65.25 | 139.00 | 160 | 22 | 11.0 | 1266.00 |
| TOTAL | - | 11057 | - | 218.00 | - | - | - | 2,751.00 |
| ENTRY POINT | - | - | - | - | 0 | - | 0.0 | - |
| KORATTUR ANICUT | - | - | - | - | - | - | 0.0 | - |
| TAMARAIPAKKAM | - | - | - | - | - | - | 0.0 | - |

A paper published in the Bulletin of the American Meteorological Society theorised human-induced factors as the major cause of climatic changes. Widespread use of wood as cooking fuel has resulted in a blanket of pollutants-aerosols. These aerosols block sunlight and act as a counter to the warming caused by greenhouse gases – mainly carbon dioxide. After studying a plethora of models, the scientists said that over the last 40 years, sea surface temperature in the Bay of Bengal along India's eastern coast has been lower than global climate models. Around the time of the heavy rainfall off the Chennai coast, this part of the Bay remained cooler than the Indian Ocean overall. Thus, this cooling seawater might have generated strong wind system to pull the moisture bearing clouds towards the land but the real reason is the human error to open the sludge gates of the reservoir on time.

On December 1, 2015, it rained 494 mm (19.45 inches) within 24 hours in Chennai. Any city without adequate natural underwater seepage capabilities would be flooded. The Chemberabakkam dam feeding the drinking water potential of Chennai was kept at a higher storage level of almost 85-88% (instead of 75%) of the total capacity of 3645 mcft. When heavy rains to the tune of nearly 48 cm fell on the reservoir on December 1, 29,000 cusecs was released over 12 hours without warning. The city of Chennai has further lost its natural water rechargeable aquifers due to water body encroachments as housing properties. For residents of rain-parched Chennai, where Metro water pipes are running dry even before summer has set in, drilling deep is a convenient way to find water. But for every extra depth that is dug to pump out water, the groundwater level drops exponentially. The Chennai Aquifer System, the crucial source of groundwater for about 1 crore people, is critical. A study by the Central Ground Water Board under the Union water resources ministry has found that Chennai's groundwater resources are over exploited, with water below the surface being extracted at a rate of 185%. Thus, this means the groundwater table in Chennai is depleting between 10cm and 20cm per year.

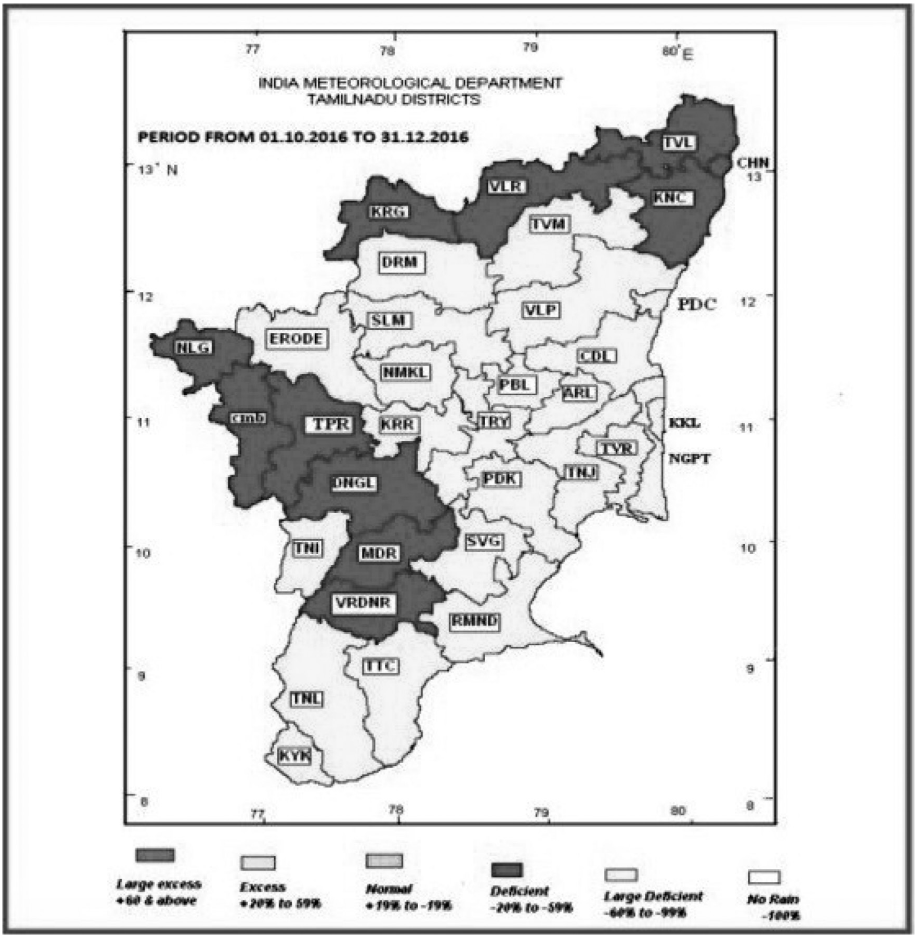
The root of the problem of drought (failing crop) and subsequent water security is lack of awareness among the farmers. The literacy rate for Tamil Nadu in 2011 has increased to 80.33 % from 73.45 % in the 2001 Census. As Dr K Sivasubramaniam told, most of the farmers could barely sign and don't have adequate knowledge of climate change other than the fact that they can't farm the way they used to. Thereby they don't understand the coping mechanism as well. Third reason for reduced water table is well irrigation. Instead of well, there should be a shift to drip or tank irrigation. As tanks are natural reservoirs of rain water and underground aquifers have been neglected both in government policies and farming techniques. The tanks along the Cauvery Pakkam belt is in dire need of desilting. Drought is the best time to desilt waterbodies. In addition, pollution of the river and canal networks has also led to deficit in clean drinking water. In Tirupur effluents from bleach and dye factories and remains from tannaries in Palar have led to water pollution.

S.Janakarajan, president of South Asia Consortium for Interdisciplinary Water Resources Studies, in an interview to the Hindu said "There are nearly 3,600 waterbodies in Tiruvallur, Chennai and Kancheepuram districts. If maintained properly, nearly 80 tmcft of water could have been stored during floods. The reservoirs that cater to the city have a capacity to store 11 tmcft." Chennai is traditionally a rain-starved city. Meteorologists note that the water scarcity is more of human-induced, as the annual rainfall has been less than 100 cm only on a few occasions since 1969.



SOURCE: RAIN CENTRE AND EXNORA INTERNATIONAL

The metropolis of 8.2 million people – by the 2011 census – has an estimated 150,000 illegal buildings, many built over what used to be natural streams, ponds and even rivers. In a report of the Parliamentary Standing Committee on Home Affairs the advisory board acknowledged the lack of timely desilting, inadequate flood zone planning and large-scale settlements in low-lying areas as major contributors to water insecurity in the city.




Grey water recycling could be an efficient answer to water insecurity. Chennai generates nearly 700 million litres of sewage daily. This could be recycled through decentralised treatment plants. It would work out cheaper at ₹28-30 per kilo litre than the desalinated water that costs ₹48 per kilo litre. The sludge could be converted into bio manure. Now, the city gets an average of 550 million litres a day from lakes, desalination plants, (Veeranam scheme) and newly included groundwater resources in Poondi and Thamaraipakkam wells. Untill now, there exists input subsidy relief of Rs 2,247 crore. This government-sanctioned amount is aimed towards providing relief to farmers reeling under water deficit. The state has taken to construction of new deep borewells, rejuvenation of existing borewells and open wells, replacement of pump-sets and supply of water through lorries in aggrieved.

*For this case study an interview with Dr.K.Sivasubramaniyan, Associate Professor, Madras Institute of Development Studies and Dr Sophie at the M S Swaminathan Research Foundation in Chennai was taken by the researchers.*

## **Eastern Coastal Plains (**States: Odisha)

According to areport in the Odisha Suntimes in 2015, the districts of Chandrasekharpur and Aiginia in Odisha are among the worst hit with groundwater level falling rapidly. As per the records of the past five years, the groundwater level in Aiginia was 4.55 meter in 2009 which slipped to 2.78 meter in 2014. Likewise, the groundwater level in Chandrasekharpur area, which was 5.95 meter in 2009, has now dropped to 4.82, a decrease of 3 meter in just five year. Odisha, being a coastal state has faced extreme weather conditions from cyclone, depressions and typhoon. But over the past few years rising sea level has led to instances of tidal erosion, floods and drought. Some climatologists attribute it to global change in climatic conditions but most label it on human-induced climate change.

The survey, conducted by the state government's groundwater survey and investigation division in Ganjam, Gajapati and Kandhamal districts, have revealed that the level of groundwater has depleted from 3.48 metres in 2014 to 4.12 metres in 2015. In the south eastern part, about 200 to 300sqkm area of Chilika area is deprived of surface irrigation.Chilika Lagoon and six blocks around cannot use surface flow due to water logging, salinity intrusion and back water. Therefore the only alternate is the ground water. But with over use of groundwater the salinity intrusion has extended up to 30 to 40km inland. The salinity rates of wells have increased after Tsunami on 26th Dec 2004 far inland exhibiting salinity intrusion. Salinity issues are acute in Kanas, west Sakhigopal and north Delang area.The depth of ground water availability during monsoon is 0-7m where as in non-monsoon period it is available at a depth of 4-20mt or even more. According to government set rules, a distance of 150 to 200 metres between borewells has to be maintained. But the rules are often flouted and excessive drilling of borewells has led to over exploitation of groundwater. Perched aquifers are also available at a very low depth of 0-3m. About 4.36BCM of ground water is being drafted with irrigation sector extracting the highest (79.6 per cent) in coastal areas of south Mahanadi delta.

The major river basins of Odisha are theSuvarnrekha, the Baitarani, the Budhabalanga, the Brahmani, the Mahanadi, the Rushikulya, the Vansadhara, Indrabati, Nagabali and Kolab. The average annual availability of surface water resources in Odisha according to a survey is 120.397 BCM. In rivers such as the Narmada and Mahanadi, the percentage utilization is quite low being 23% and 34%, respectively.

According to environmentalists, the city receives around 1,500 mm of rainfall every year, but the number of rainy days has gone down. Earlier, the average rainfall was from 70 to 82 days during the three-month monsoon season, but it has dropped to 60 now. The state has been declareddisaster-affected for the past two decades. Since 1965, these calamities have not only become more frequent, they are also intense with more destructive capability. For instance, a heatwave in 1998 killed around 2,200 people -- most of the casualties were from coastal Orissa, a region known for its moderate climate. Since 1998, almost 3,000 people have died due to heatstroke. Between 1998 and2007, the annual mean maximum temperature has increased by 0.40C at Gopalpur, 0.50C atBhubaneswar and 1.10C at Paradeep. When it comes to tidal erosion, 20 other villages along the coast are at high risk. Most have lost around 60 per cent of their land to the sea. Drought in 2001 caused an economic loss of about Rs643 crore in Odisha, due to crop damage and affected 11 million people. Floods in 2001 inundated 25 of the 30 districts. Due to such calamities, an average 9,00,000 hectare of agricultural land lose crop every year. During the last 14 years, annual rainfall showed increasing trend in the coastal districts and declining in the interior districts except Kalahandi. But the number of rainy days in the state has declined by 5-7 days in the last 40 years.

There has been a dispute between Chhattisgarh and Odisha over the damming of Mahanadi. Chhattisgarh being the upper riparian state benefits from the developmental works in Mahanadi but at the same time deprives water to the agricultural lands in Odisha. The onus to resolve the conflict (at the administrative level) has been taken up many civil societies in both the states. Several Mahanadi peace rallies have been taken out in the two states of Odisha and Chhattisgarh to connect people of both the States to the mother river and resolve the water dispute amicably. The campaign for peace, 'Mahanadi Peace Initiative', was formed by the Odisha-based Mahanadi River Waterkeeper and Chhattisgarh-based Nadi Ghati Morchha.

## Western Coastal Plains (State: Goa)

Located on the coastal region, Goa is often faced with climatic extremes like tidal erosion and depression, thus leading to water problems. However, it is the anthropogenic activities like mining, tourism, mega-housing projects with high-rise buildings, purchase and sale of land that is responsible for environmental pressure and degradation. Cities in Goa, mainly Panjim, Vasco, Margao and Mapusa have been experiencing frequent smoggy days during the winter. Panjim is most affected by the smog, which is caused by temperature inversion and trapping of atmospheric dust and exhaust gases. Episodes of respiratory disorders shoot up during these smoggy days. And chances are that the frequency of smoggy days with poor air-quality will increase in almost all the cities in the state, in the near future.

As the Nobel Peace Prize winner, Rajendra Pachauri told in an interview, the city of Panaji (this tiny riparian state) is "very vulnerable"due to thermal expansion of the oceans combined with rising sea levels due to global warming. The sea level rise is predicted to be around 98 cm. This could inturn have an impact on river flooding and coastal inundation.

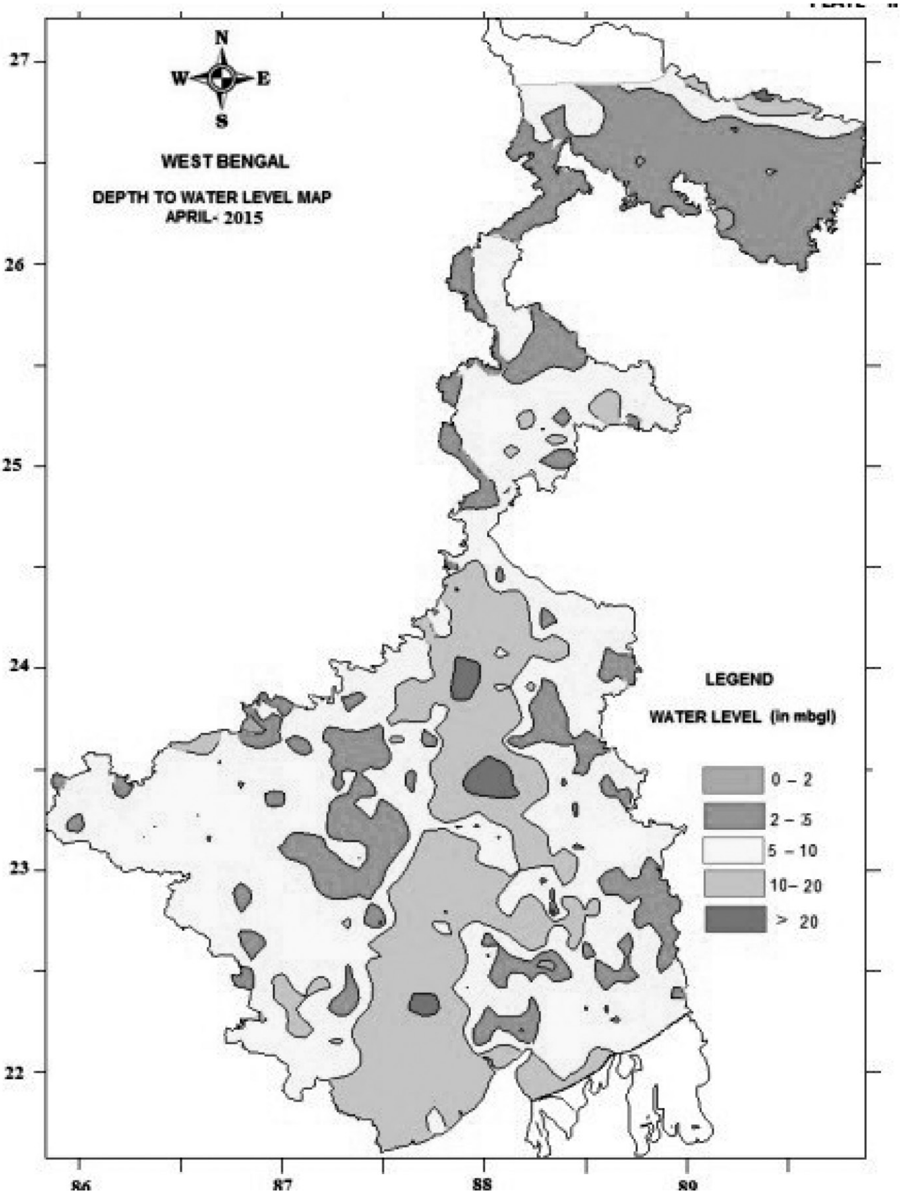
The Water Resource Department has estimated thatgroundwater level in 11 coastal villages had gone down to 8.97m below ground level in May 2009 from the level of 8.30m recorded in May 2008. In Anjuna, it dropped to 7.44m in May 2012 from 6.69m recorded in May 2010. This fall may not be drastic but given the population growth and the added pressure from the tourism sector the exploitation of the aquifers may become a concern. Whereas, the change in ground water level for other nine villages was within the range of -0.21m to +0.17m. In the South Goa district, the water level is in therange of less than 2 to 20 m bgl. Water level in the range of 10 to 20 m bgl isseen only the small pockets of Salcete, Canacona and Sanguem taluks. Estimating the data for the pre-monsoon period in 2011, (May 2001 to May 2010) 12 wells (60%) show a rise in water level. The remaining 8 wells (40%) show a fall in water level. In the district of North Goa, extensive mining area at specific locations has impacted both shallow and deep groundwater system in the districts. In a study done by the Indian Journal of Science and Technology, titled, 'Assessment of Groundwater Quality in the Mining Areas of Goa, India,' it was estimated that the mining activities have however not impacted the water level contamination considerably.

In the Konkan coast of Goa, rainfall has exceeded by 30%, according to theIMD data for 2017. The current season had shown a surplus for a few days after the monsoon hit Goa on June 8. But after a few days, the weak monsoon activity sprung up a deficit, which has continued throughout the season. The poor rainfall activity during the peak month of July had showed a deficit of 24%, as the total rainfall during the month was 840.0mm as against the normal of 1104.1mm. The State Agriculture department has targeted to cover 28,000 hectare area in Goa under the paddy cultivation. But this deficit of rain will hamper the farmers in Salcette, Bardez and Tiswadi areas where almost 50 per cent of their plantings has been completed. Water insecurity in Goa may not be that acute as the state is equipped legally with the Policy on Rain Water Harvesting - Department of Water Resources (Government of Goa) (2008) and civil society initiatives. Located on the windward side of the Western Ghats, rainfall has become erratic with late onset but the amount hasn't gone down. It is only with underground water depletion that seems to be a concern.

## **Bengal and Assam plains (**States: Bengal and Assam)

In West Bengal, the main sources of water for consumption are the Ganga river system and the groundwater borewells. The river system encompasses the catchment areas of the Mahananda, Jalangi, Bhairab in the eastern part and the Mayurakshi, Ajoy, Damodar, Dwarakeshwar and Kasai in the western part. The Teesta, Torsa and Jaldhaka, streams off the Brahmaputra,in the northern part of the State. Beside these, there is a small independent river basin, namely the Subarnarekha basin covering the southwestern part of the State.

According to the groundwater statistics by the CGWB, during the pre-monsoon season last year, the southern part of the state with shallow aquifers, depth of water level ranged between 2-5 m bgl. On the other hand, confined aquifers of Haora, East Medinipur, South 24 Parganas showed a deeper water level of 5-10 m bgl and 10-20m. Annual fluctuation in water level between April 2014 and April 2015 was within 0-2 m. Out of 1120 analyzed wells, 530 wells were grouped under falling zone category and 590 wells are grouped under rising zone category. The rise and fall of water level is mostly restricted within 0-2 m (42.1% shows rise and 36.1% shows fall).In Kolkata city, the piezometric-level (level to which water in a confined aquifer would rise) generally varied from 14.50m bgl – 16.50 m bgl. This is due to huge withdrawal of groundwater for domestic and industrial uses. The groundwater scenario worsens in the Sunderbans area as over exploitation and lack of maintenance has led to brackish/saline water table.




Map 6: Groundwater level (pre monsoon) in West Bengal (2015)

*Source: Groundwater Statistics by the CGWB*

For past few years, disaster events like floods, heavy rain and landslides have ravaged the state of Assam. From April 2017, flood has ravaged Bordubatop village in Morigaon, Dhemaji, Lakkhimpur, Barpeta, Bongaigaon, Dhubri, Nagaon, Dibrugarh and Hailakandi districts. In Dhemaji, 496 villages have flooded, with nearly 1,76,566 affected persons and 96 affected villages.In Majuli, 58 villages have submerged, affecting 48,381 persons. These are also the areas facing severe drinking water crisis. According to the district administration, a huge number of localities in the city are facing water shortage. People said a major reasons for the problem is the haphazard drilling of deep tube wells in residential areas and selling the water from them commercially.

According to a public statement by the Assam State Disaster Management Authority, around 1,115 tubewells are left contaminated by the flood. Nearly 12,00,000 hand tubewell and electric pump sets in lower Assam districts are running dry because of fast depletion of the water table. The situation further compounded following the drying up of the river basin and deficient rainfall for the past few years. Officials at the lower Assam districts' urban water supply department said in a public statements that deep water boring to the level of 120 feet now has failed to pump out water. As the water table has fallen below 100 feet, people are not getting water for the past five years. The problem becomes acute from December to March.

At present in Guwahati, the Guwahati Municipal Corporation (GMC), Public Health Engineering Department and Assam Urban Water Supply and Sewerage Board are primarily involved in distribution of domestic water supply mainly drawn from Brahmaputra. However, the water supplied by these agencies meets the demands of just 30 % of the city's population. The total installed capacity of potable water generation under GMC area is around 98 MLD (Million Litre per Day) while the requirement is as much as 132 MLD. This indicates lack of infrastructure to cope with the rising population and the subsequent rise in water demand.

Guwahati experiences an average annual rainfall of about 162cm, which is less than the average annual rainfall of about 220 cm for the state as a whole. The average number of rainy days per year in the city is about 110 days. The annual rainfall in the Brahmaputra valley has shown a decreasing trend by the rate of 72.0 mm/decade during last three decades (1981-2010). This decreasing trend was mainly contributed by significant decrease in monsoon rainfall (103.8 mm/decade).

According to the Regional Meteorological Centre, Assam recorded a maximum temperature of 38.5 degrees Celsius last year, the highest in the last 33 years. The annual mean temperature in the Brahmaputra valley increased significantly due to rise in both maximum and minimum temperature in the last 60-years (1951–2010). The maximum increase was noticed in post-monsoon period. The warming trend in the valley was particularly pronounced in the recent 30 years period and was 1.6 times higher than all-India average. The rise in temperature has been attributed to the deficit in pre-monsoon rainfall.

**FIGURE AT A GLANCE, 2012**

| | |
|---|---|
| **Seasonwise Rainfall (all seasons)** | |
| Actual | 2151.8mm |
| Normal | 2295.8mm |
| Departure from Normal | (-)6.27% |
| Status | Normal |
| **Winter Season** | |
| Actual | 14.5mm |
| Normal | 48.2mm |
| Departure from Normal | (-)69.92% |
| **Summer Season** | |
| Actual | 420.4mm |
| Normal | 455.2mm |
| Departure from Normal | (-)7.64% |
| **Monsoon Season** | |
| Actual | 1555.0mm |
| Normal | 1523.9mm |
| Departure from Normal | 2.04% |
| **Post Monsoon** | |
| Actual | 161.9mm |
| Normal | 168.5mm |
| Departure from Normal | (-)2.00% |

Table 5: Rainfall estimate for Assam (2012)

*Source: Statistical handbook of Assam, 2013*

**North-Eastern Hills (**States: Arunachal Pradesh, Sikkim, Manipur, Mizoram, Tripura, Nagaland and Meghalaya)

As per the International Water Management Institute records, only 21% of households in NE India (occupying 8% of India's landmass and about 4% of the total population of India, as per the 2011 census) have reportedly access to tap water as the main drinking water source even though there is enough annual rainfall. This is due to lack of conservation practices. Though certain traditional practises of water conservation exist but developmental activities in the form of dam construction, road and bridge construction in this young fold mountain region has made the zone more susceptible to disasters.

In Imphal, Manipur, around 7.55 lakh estimated population and sub-urban areas including floating population of para-military forces need 101.9 million litres per day, according to the Public Health Engineering Department. Efforts by the administration are also being made to bridge the demand supply gap as the actual production from 17 water supply plants is hardly 70 MLD against its installed capacity of 101.3 MLD. Besides rainwater and groundwater, wetlands are also one the water sources in Imphal. It comprises of 1820 sq km of flat alluvial valley and 20,507 sq km of hilly terrain. Apart from water crisis in the bowl-shaped valley, the nine hills surrounding Imphal are also facing water depletion due to rampant deforestation. In R K Rajan Singh authored chapter, 'Tipaimukh High Dam on the Barak River,' in *Water Conflicts in Northeast India,* states that construction of the Tipaimukh dam will lead to permanent displacement and loss of livelihoods of indigenous communities, mostly belonging to the Zeliangrong and Hmar people. A total of 25,822 hectares of forest area in Manipur will be affected by this which will lead to felling of 7.8 million trees. In addition, the major rivers that pass through the Imphal areas, namely the Imphal, the Iril, will rapidly go dry. All the rivers in Manipur empty into the Loktak Lake. But the National Hydroelectric Power Project has been generating 105 MW using the lake water around the clock. This is one of the reasons for the depleting water level since water used by the three turbines is siphoned off towards Assam instead of recycling it.

In Aizwal, Mizoram, in spite of good rainfall of more than 2,000 mm in the district, there is acute shortage of water during summer, because most of the rain water flows out as surface run off. Transboundary issues like building of dams by China on the Brahmaputra River have given rise to serious apprehension and concerns over water availability in the region. An already conflict-striven region, with increasing water perils, a transboundary/interstate disputes over water sharing might erupt. Landslide dams getting breached or diffused in Bhutan or Tibet have caused catastrophic floods in downstream areas in Arunachal and Assam. Unwarranted release of water to rivers from dams both in Bhutan and within the region has caused devastating flash floods in the plains. Lack of coordination and cooperation between countries sharing the river basins is a major obstacle in resolving these problems. The scope for ground water storage is limited mostly to secondary porosities controlled by structures. These aquifers are the main source of springs. Ground water emanating in the form of springs are being developed for use as a source for water supply. In South Tripura district, the trend analysis showed that both pre-monsoon and post-monsoon groundwater depths have declining trends in places like Harshumukh. Conversely, an increasing trend was estimated in places like Gorjee Bazar, Subroom and Udaipur and a uniform trend at Santir Bazar.

## Case Study:Water Security and Sohra[10] in Meghalaya

"Sohra is not the wettest place anymore," said Vijay Kumar Singh, Range Officer, Meteorological Department, Sohra. In November 1999, for the first time, a Sohra (formerly Cherrapunji) resident, Nitin Gogoi, wrote about this phenomenon in his blog, later carried by Rediff news. "It is perhaps the ultimate irony," he wrote, "The Khasis, who inhabit Cherrapunjee have to worry about" water shortage. Sohra lies in a small valley among the hills of East Khasi. "There was a time when denizens of Cherrapunjee, reputed to be the wettest place in the world, invoked Lae Slat, the rain god, to stop the rain. On occasions such as funerals, when gathering mourners was difficult because of incessant rain and wind that sometimes beat down for weeks on end, village elders would sit under a banana tree and pray for the rain to end, at least for one day, in one village," Teresa Rehman, a Northeast-based journalist for the Thomson Reuters Foundation wrote in 2010.

'Now the people have to pray for rains,' said Vijar Kumar Singh. Large scale deforestation and industrialization in the form of limestone quarrying has affected rainfall patterns in the valley. The Meteorological Department at Sohra said orographic pattern of rain in northeast India is shaped by the high hills and mountains in the region. However, relentless quar-rying has decreased size of some Khasi Hills which in turn has reduced the amount of rainfall.

According to the statistics provided by the Meteorological Department in 2013, rainfall has declined from 12,261.6mm in 2000 to 7,560.3mm in 2013, recording

10 *This case study was done independently by the author in 2013.*

a reduction of 4,701.3 mm of rainfall over a decade in Sohra. Rains are the only source for the perennial streams and natural reservoirs from where many villages receive their drinking water. "Even before winter, the streams and the reservoir dry up, creating a water crisis. We are now compelled to depend on costly packaged drinking water," said Bah Homeland, a teacher from Kong Thong village. Indeed, Subir Bhaumik, a Kolkata based BBC correspondent reported that long rows of trucks loaded with water drums can be seen travelling to Cherrapunjee from the plains.

Some tankers, normally in the business of carrying oil are loaded with water and incur huge profits by selling supplies in Sohra. Water is a source of income for many who depend on tourism. A change in rainfall pattern has lead to water depletion in the Nohkalikai falls, a major tourist attraction. Constant deforestation and burning of forest for cultivation has chan-ged the foggy picturesque dell into a barren hill town. The people have shifted from tourism to daily labour in the cement companies like Cherasima Limited. Teibor Rajee, a 24 year old hotel manager, said "The quarry stretches from Sohra to Assam. Along the roads of Mawsmai, Burnehar toShillong and Guwhati, one can find trucks loaded with cement." Though the limestone quarry has generated employment opportunities, it has come at the cost of health and environment.

"Breathing the dusty air and smoke has increased the possibility of diseases such as asthma and tuberculosis. Labourers working for a prolonged period in the lime kilns are often victims of lung cancer," said Teibor Poonendu Kumar Pal, a 68 year old high school teacher and a shop- keeper has lived in Sohra since 1947. He said, "Over the years, there has been a rise in temperature. We are unable to cultivate vegeta- bles which grew in this climate such as cauliflowers, tree tomatoes, green chillies and spinach."Cutting of the hills has increased

the soil erosion. Sincerity Phanbuh,Public Relation Officer, Government of Meghalaya said, "The Forest department has taken up the responsibility of planting trees."

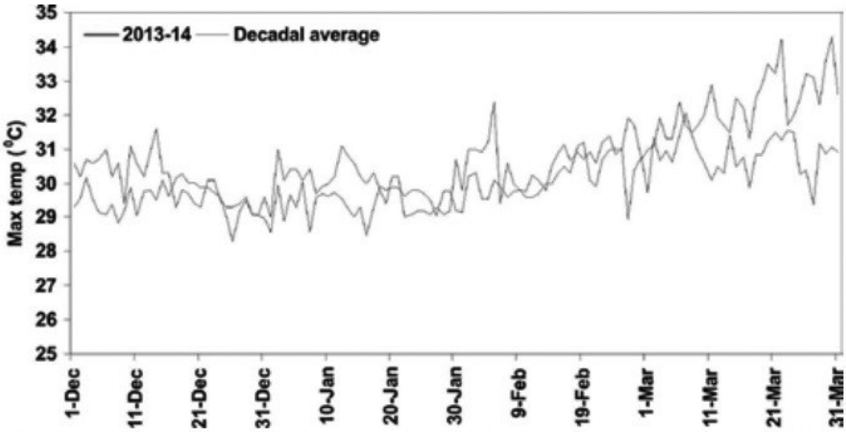
## **Islands (**State: Andaman, Nicobar)

The physiography of Andaman and Nicobar is one of the most important factors influencing the islands' vulnerability to climate change. It is manifested in the form of coastal erosion, stream flow and increase in sea level. The Nicobar Islands are surrounded by shallow seas and coral reefs. Baring a few Islands the terrain is mostly undulating with main ridges running North-South. In between the main ridges deep inlets and creeks are formed by submerged valleys. In most of the Islands perennial streams are non – existent except in Great Nicobar where there are five perennial rivers. In Great Nicobar, the important perennial streams are Galathea, Jubilee, Dark Anaing, Dark Tayal, Amrit Kaur.

An analysis of the historical rainfall data since 1951 indicate no significant change in the average decadal rainfall though the pattern of rainfall has changed with increase in the number of extreme rainfall events. It has also highlighted decreasing trend in rainfall and rainy days over Andaman and Nicobar Islands in winter and post-monsoon seasons which has negative consequences on fresh water aquifers.

In May 2015, depth of water levels mostly range from 0-2 mbgl (43.5%) followed by 2-5 mbgl (47.2%) and 5-10 mbgl (8.3%). In the year 2005-15, out of 108 well, 73 wells show rising trend of water level in the tune of 0.058 to 4.1 m/yr. Rest 35 wells show falling trend of water level in the tune of 0.002 to 4.54 m/y. Ground water is the main source of drinking water supply in these islands. About 90% of the dry bore well were in compressed sedimentary deposits, which act aquitard whereas rocky subsoil formation was found to be more successful (CGWB, 2010). It has been experienced that the scarcity of fresh water is often a limiting factor for socio-economic development of Nicobar as in the case of other small islands.

One of the striking features observed after the 2004 Indian Ocean tsunami was the impact on those areas which are located behind dense mangrove patches than the terrain directly exposed to the tsunami waves. The digital elevation of Nicobar Islands indicated that among the islands, Trinket and Chowra have over 15% of the total land area with an elevation less than 10 m above mean sea level and are thus significantly vulnerable to climate change events particularly of wave action and coastal inundation. Yet another important aspect of A&N Islands which expose to vulnerability is earthquake. These Islands lie in the most severe seismic zone (zone V), where the expected intensity of seismic shaking is IX or greater on the MSK intensity scale (Rai et al. 2005). Further, massive earthquakes also result in the alteration of island topography leading to submergence of the islands which further exacerbate the impact of sea surges. Analysis of the estimated area that will be affected with 0-5 m increase in sea level revealed that the loss of land varies from 1-14% and it would be greatest in Chowra where about 13% of island will be inundated.




Graph 5: Post-monsoon season changes in maximum air temperature (2013-14)

Similarly the long term average of mean air temperature showed increasing trend, more significantly the post-monsoon average. During 2013-15, it was 15% higher than the decadal average resulting in drying up of many of the freshwater pond and falling of ground water level in the islands. Owing to factors of limited size, availability, and geology and topography, water resources of Nicobar Islands are extremely vulnerable to seasonal changes and variations in climate, especially in rainfall. As these islands are not suitable for large scale development of surface storage facilities, decentralized rainwater harvesting and recharging the shallow water table is the only option.

## Conclusion

In India, the 'scarcity' dilemma with regard to water security lies in inefficient water distribution/management and climate change is a mere catalyst to the existing peril. The data analysed gives us a picture that the climatic changes affecting South Asia is in congruent with the global climate change conditions. Severe summer, late monsoons, extreme downpour and less winter months are common to all the zones in the country. As water replenishment and availability is directly proportional to the hydrological cycle, late monsoons and severe summer has given rise to water scarcity in the country. As IPCC defines, climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. It should be noted that in India, man-made developmental activities are greatly responsible for these climatic conditions which in turn has stressed water availability.

The water resources in the country are unevenly distributed. This brings in the necessity to build a water regulatory body to monitor the frequent usages.

As the country lacks any such concrete policies the onus shifts to the civil society to ensure responsible usage of water. In arid and semi-arid zones of India, water scarcity has been significantly overcome due to civil society initiatives. While in Punjab and Haryana, the rice bowl of India and land of five rivers, faces acute water shortage due to overexploitation of groundwater for irrigation. Poor water quality is also a major environmental issue in India as most of its river networks, lakes and surface water are polluted. As a result, more than 100 million Indians live in areas where water is severely polluted. Lastly, leakages and lack of proper technology has led to 50 per cent of India's piped water supply wasted.

Thus we see poor infrastructure, lack of policy planning, pollution and other developmental projects are the primary and first hand cause of water shortage in India. However, it is these very activities that has spiralled anomalies in the climatic conditions thereby aggravating the already water stressed situation in India.

## References


"Assam floods effect: drinking water scarcity leaves many in distress," *The Northeast Today*, 17 July, 2017
Accessed: 28 August, 2017
URL:https://thenortheasttoday.com/assam-floods-effect-drinking-water-scarcity-leaves-many-in-distress/

"Andhra Pradesh records deepest groundwater level in the country," *Deccan Chronicle*, 4 July, 2017 Accessed: 6 July, 2017
URL: http://www.deccanchronicle.com/nation/current-affairs/040717/andhra-pradesh-records-deepest-groundwater-level-in-the-country.html

"Bihar govt to set up control room to manage water crisis," *The Times of India*, 14 April, 2016
Accessed: 1 August, 2017
URL: http://timesofindia.indiatimes.com/good-governance/bihar/Bihar-govt-to-set-up-control-room-to-manage-water-crisis/articleshow/51821874.cms

Borah, Amarjyoti,"Assam reels under unseasonal heat wave, water shortage," Down to Earth, 05 May, 2014
Accessed: 28 August, 2017
URL:http://www.downtoearth.org.in/news/assam-reels-under-unseasonal-heat-wave-water-shortage-44226

"Climate change and Nicobar Islands: Impacts and adaptation strategies," *Journal of the Andaman Science Association* Vol. 20(1):7-18 (2015), ISSN 0970-4183

Climate Change in Madhya Pradesh: Indicators, Impacts and Adaptation, *Indian Institute of Management Ahmedabad* (2016) W.P. No. 2016-05-05

"Changing rainfall pattern damaging agriculture in MP," *Hindustan Times*, 06 April, 2016
Accessed: 5 August, 2017
URL:http://www.hindustantimes.com/bhopal/changing-rainfall-pattern-damaging-agriculture-in-mp/story-ykLXaLGnFS4P1BkJDUuSFI.html

"City groundwater depleting, at risk of contamination," The Tribune, 24 August, 2015
Accessed: 5 August, 2017
URL:http://www.tribuneindia.com/news/jammu-kashmir/city-groundwater-depleting-at-risk-of-contamination/123463.html

"Climate change: Clear and present danger in Kashmir," *Livemint*, 23 April, 2015
Accessed: 5 August, 2017
URL:http://www.livemint.com/Politics/jwYMXBkqZSuIEKuAiQiARP/Climate-change-Clear-and-present-danger-in-Kashmir.html

"Groundwater Yearbook, Bihar (2015 - 2016)," *Ministry Of Water Resources,* Central Ground Water Board (2016)
Accessed: 1 August, 2017
URL: http://www.cgwb.gov.in/Regions/GW-year-Books/GWYB-2015 16/GWYB%20 MER%20(Bihar)%202015-16.pdf

"Groundwater Yearbook of West Bengal and Andaman and Nicobar Islands(2015 - 2016)," Ministry Of Water Resources, Central Ground Water Board (2016)
Accessed: 13 June, 2017
URL: http://www.cgwb.gov.in/Regions/GW-year-Books/GWYB-2015-16/GWYB%20 ER%202015-16.pdf

"Groundwater Scenario in South Tripura District of North-East India," 20th International Conference on Hydraulics, Water Resources and River Engineering, IIT Roorkee, (2015)
Accessed: 28 August, 2017
URL:https://www.researchgate.net/publication/290117636_Groundwater_Scenario_in_South_Tripura_District_of_North-East_India

"Groundwater levels depleted by North Goa hotels: CAG," *The Times of India*, 14 October, 2013 Accessed: 8 June, 2017
URL: http://timesofindia.indiatimes.com/city/goa/Groundwater-levels-depleted-by-North-Goa-hotels-CAG/articleshow/24109035.cms

"Groundwater level dips in lower Assam," *The Telegraph,* 5 April, 2012
Accessed: 28 August, 2017
URL:https://www.telegraphindia.com/1120405/jsp/northeast/story_15334759.jsp

"Haryana govt working towards checking groundwater depletion," *The Pioneer*, 06 September, 2015
Accessed: 5 August, 2017
URL http://www.dailypioneer.com/state-editions/chandigarh/haryana-govt-working-towards-checking-groundwater-depletion.html

Kabirdoss Yogesh, "Groundwater level in Chennai hits 'critical state'," *The Times of India,*30 March, 2017
Accessed: 5 August, 2017
URL: http://timesofindia.indiatimes.com/city/chennai/groundwater-dips-20cm-per-year-as-chennai-overexploits-aquifers/articleshow/57905446.cms

Maneesh P, C. Muniyandi, "Depleting Sustainability: A Detailed Study on Ground Water Situation in Kerala," *International Journal of Arts and Humanities*, Spring Journals, Vol. 5(1): pp 187-191, (2017)

"Manipur facing acute drinking water shortage," *The Hindu*, 19 May, 2016
Accessed: 28 August, 2017
URL:http://www.thehindu.com/news/national/other-states/manipur-facing-acute-drinking-water-shortage/article5819061.ece

Rajwi, Tiki, "Water level frighteningly low in Kerala dams: Report," *The New Indian Express*, 05 March, 2017
Accessed: 5 August, 2017
URL:http://www.newindianexpress.com/states/kerala/2017/mar/05/water-level-frighteningly-low-in-kerala-dams-report-1577753--1.html

Ramani, Srinivasan and Vasanth Srinivasan, "A wrong call that sank Chennai," *The Hindu*, 10 December, 2015
Accessed: 5 August, 2017
URL:http://www.thehindu.com/news/cities/chennai/chennai-floods-a-wrong-call-that-sank-the-city/article7967371.ece

Singh, Chandra Shekhar *et al.* "Disastrous Challenge due to Climate Change in Bihar, Developing State of India," *International Journal of Scientific & Engineering Research,* Volume 5, Issue 6, (2014)

"Temperatures in Madhya Pradesh to surge by 2045, increasing drought conditions: Study," *The Indian Express,* 06 June, 2016
Accessed: 5 August, 2017
URL:http://indianexpress.com/article/india/india-news-india/temperatures-in-madhya-pradesh-to-surge-by-2045-increasing-drought-conditions-study-2837111/

"The Maharashtra Groundwater (Development and Management) Act 2009," India water portal, 25 April, 2015
Accessed: 6 July, 2017
URL: http://www.indiawaterportal.org/articles/maharashtra-groundwater-development-and-management-act-2009

Venkatesan D, Suresh Gandhi M and Manjulav, "Long-term rainfall trend of Kerala, Tamil Nadu and Pondicherry using departure analysis," *International Journal of Earth Sciences and Engineering*, Vol:08, No. 01 (2015)
Accessed: 22 August, 2017
URL: https://www.researchgate.net/publication/298649039_Long-term_rainfall_trend_of_Kerala_Tamil_Nadu_and_Pondicherry_using_departure_analysis

Venkat Vidya, "Gangotri glacier retreated by 3 km in two centuries," *The Hindu*, 04 March, 2017 Accessed: 5 August, 2017
URL: http://www.thehindu.com/sci-tech/energy-and-environment/gangotri-glacier-retreated-by-3-km-in-two-centuries/article14386191.ece

"With depletion of forest cover, water scarcity looms large in Manipur," *Eastern Mirror*, 16 October, 2016
Accessed: 28 August, 2017
URL:http://www.easternmirrornagaland.com/with-depletion-of-forest-cover-water-scarcity-looms-large-in-manipur/

"Water crisis looms in Tamil Nadu, with just 7-8% storage in reservoirs," *Business Standard*, 1 April, 2017

Accessed: 5 August, 2017
URL:http://www.business-standard.com/article/economy-policy/water-crisis-looms-in-tamil-nadu-with-just-7-8-storage-in-reservoirs-117040100687_1.html

"68% wells in MP show fall in groundwater level," *Hindustan Times*, 14 January, 2016
Accessed: 5 August, 2017
URL:http://www.hindustantimes.com/bhopal/68-wells-in-mp-show-fall-in-groundwater-level/story-3ENnrdoHY96CYyUkpJmryN.html

"22 districts in Uttar Pradesh still await 'sufficient' rain for sowing paddy," *Hindustan Times*, 13 July, 2017
Accessed: 5 August, 2017
URL:http://www.hindustantimes.com/lucknow/22-districts-in-uttar-pradesh-still-await-sufficient-rain-for-sowing-paddy/story-cXEdJOqzZnvIFUqB6f4vML.html